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C E R T I F I C A T I O N

I, Takashi KOJIMA of Ginza Ohtsuka Bldg., 2F, 16-12, Ginza 2-chome, Chuo-ku, Tokyo, Japan, hereby certify that I am the translator of the accompanying certified official copy of the documents in respect of an application for a patent filed in Japan on the 10th of March, 1995 and of the official certificate attached thereto, and certify that the following is a true and correct translation to the best of my knowledge and belief.

Dated this 13th day of September, 2002

Takashi KOJIMA

(Translation)

Request Sending Priority Document to PCT

To: Mr. Yuji KIYOKAWA
The Commissioner of the Japanese Patent Office

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International Patent Application which presentation on March 8, 1996

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3. Applicant:

Name	NISSAN CHEMICAL INDUSTRIES, LTD.
Address	7-1, Kandanishiki-cho 3-chome, Chiyoda-ku, Tokyo, 101 Japan
Nationality	Japan
Abode	Japan
Name	Fumie SATO
Address	3-1-219, Kugenumahigashi, Fujisawa-shi, Kanagawa-ken, 251 Japan
Nationality	Japan
Abode	Japan

4. Agent:

Name	(7930) Patent Attorney Takashi KOJIMA
Address	GINZA MORISAWA Bldg., 3F, 13-19, Ginza 2-chome, Chuo-ku, Tokyo, 104 Japan

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(Translation)

Request for Certifying Priority (PCT)

To: Mr. Yuji KIYOKAWA
The Commissioner of the Japanese Patent Office

1. Number of Application: 7-079685 (1995)

2. Requestor:

Identification No.	100079304
Address	GINZA MORISAWA Bldg., 3F, 13-19, Ginza 2-chome, Chuo-ku, Tokyo, 104 Japan
Name	Takashi KOJIMA
Phone	03-3545-6454

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[Title of the Invention]	TITANIUM CATALYST AND ORGANOTITANIUM REACTING REAGENT, PRODUCTION THEREOF, AND REACTION THEREBY
[Number of the Claims]	21
[Inventor]	
[Address]	3-1-219, Kugenumahigashi, Fujisawa-shi, Kanagawa-ken, Japan
[Name]	Fumie SATO
[Applicant]	
[Identification Number]	000003986
[Name]	NISSAN CHEMICAL INDUSTRIES, LTD.
[Representative]	Shuichi TOKUSHIMA
[Applicant]	
[Identification Number]	000172282
[Name]	Fumie SATO
[Agent]	
[Identification Number]	100079304
[Patent Attorney]	
[Name]	Takashi KOJIMA
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[Document]	Specification	1
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7-079685

[SPECIFICATION]

[TITLE OF THE INVENTION] TITANIUM CATALYST AND ORGANOTITANIUM REACTING REAGENT, PRODUCTION THEREOF, AND REACTION THEREBY

[CLAIMS]

[Claim 1] A titanium catalyst for reaction between a carbon-carbon unsaturated bond and a compound having an electrophilic functional group or an electrophilic reagent, said titanium catalyst being composed of a titanium compound represented by the formula (1) below

$$TiX^1X^2X^3X^4 \quad (1)$$

(where X^1, X^2, X^3, and X^4 denote independently a halogen atom, C1-20 alkoxyl group, aralkyloxy group, aryloxy group, or -NRxRy group (where Rx and Ry denote independently a C1-20 alkyl group or aralkyl group), and any two of X^1, X^2, X^3, and X^4 may form a ring.) and a Grignard reagent represented by the formula (2) below in a molar amount 1-10 times as much as the titanium compound.

$$R^1MgX^5 \quad (2)$$

(where R^1 denotes a C2-10 alkyl group having a hydrogen atom at the β position and X^5 denotes a halogen atom.)

[Claim 2] The titanium catalyst as defined in Claim 1, wherein the titanium compound is one which has an asymmetric ligand.

[Claim 3] A process for producing a titanium catalyst for reaction between a carbon-carbon unsaturated bond and a compound having an electrophilic functional group or an electrophilic reagent, said process comprising reacting a titanium compound represented by the formula (1) below

$$TiX^1X^2X^3X^4 \quad (1)$$

(where X^1, X^2, X^3, and X^4 denote independently a halogen atom, C1-20 alkoxyl group, aralkyloxy group, aryloxy group,

or -NRxRy group (where Rx and Ry denote independently a C1-20 alkyl group or aralkyl group), and any two of X^1, X^2, X^3, and X^4 may form a ring.) with a Grignard reagent represented by the formula (2) below in a molar amount 1-10 times as much as the titanium compound.

$$R^1MgX^5 \qquad (2)$$

(where R^1 denotes a C2-10 alkyl group having a hydrogen atom at the β position and X^5 denotes a halogen atom.)

[Claim 4] The titanium catalyst as defined in Claim 3, wherein the titanium compound is one which has an asymmetric ligand.

[Claim 5] An organotitanium reacting reagent which is composed of a titanium compound represented by the formula (1) below

$$TiX^1X^2X^3X^4 \qquad (1)$$

(where X^1, X^2, X^3, and X^4 denote independently a halogen atom, C1-20 alkoxyl group, aralkyloxy group, aryloxy group, or -NRxRy group (where Rx and Ry denote independently a C1-20 alkyl group or aralkyl group), and any two of X^1, X^2, X^3, and X^4 may form a ring.), a Grignard reagent represented by the formula (2) below in a molar amount 1-10 times as much as the titanium compound,

$$R^1MgX^5 \qquad (2)$$

(where R^1 denotes a C2-10 alkyl group having a hydrogen atom at the β position and X^5 denotes a halogen atom.), and a compound having a carbon-carbon unsaturated bond.

[Claim 6] The organotitanium reacting agent as defined in Claim 4, wherein the titanium compound is one which has an asymmetric ligand.

[Claim 7] The organotitanium reacting reagent as defined in Claim 5 or 6, wherein the compound having a carbon-carbon unsaturated bond is any of olefin compounds, acetylene compounds, or allene compounds.

[Claim 8] A process for producing an organotitanium reacting reagent, said process comprising reacting together a titanium compound represented by the formula (1) below

$$TiX^1X^2X^3X^4 \quad (1)$$

(where X^1, X^2, X^3, and X^4 denote independently a halogen atom, C1-20 alkoxyl group, aralkyloxy group, aryloxy group, or -NRxRy group (where Rx and Ry denote independently a C1-20 alkyl group or aralkyl group), and any two of X^1, X^2, X^3, and X^4 may form a ring.), a Grignard reagent represented by the formula (2) below in a molar amount 1-10 times as much as the titanium compound,

$$R^1MgX^5 \quad (2)$$

(where R^1 denotes a C2-10 alkyl group having a hydrogen atom at the β position and X^5 denotes a halogen atom.), and a compound having a carbon-carbon unsaturated bond.

[Claim 9] The process as defined in Claim 8, wherein the titanium compound is one which has an asymmetric ligand.

[Claim 10] The process as defined in Claim 8 or 9, wherein the compound having a carbon-carbon unsaturated bond is any of olefin compounds, acetylene compounds, or allene compounds.

[Claim 11] A process for addition reaction which comprises performing addition reaction on a compound having a carbon-carbon unsaturated bond and a compound having an electrophilic functional group or an electrophilic reagent, in the presence of a titanium compound represented by the formula (1) below

$$TiX^1X^2X^3X^4 \quad (1)$$

(where X^1, X^2, X^3, and X^4 denote independently a halogen atom, C1-20 alkoxyl group, aralkyloxy group, aryloxy group, or -NRxRy group (where Rx and Ry denote independently a C1-20 alkyl group or aralkyl group), and any two of X^1, X^2, X^3, and X^4 may form a ring.) and a Grignard reagent

represented by the formula (2) below in a molar amount 1-10 times as much as the titanium compound,

$$R^1MgX^5 \qquad (2)$$

(where R^1 denotes a C2-10 alkyl group having a hydrogen atom at the β position and X^5 denotes a halogen atom.)

[Claim 12] A process for addition reaction which comprises adding to the organotitanium reacting reagent defined in Claim 5 a compound having an electrophilic functional group or an electrophilic reagent, thereby performing addition reaction on a compound having a carbon-carbon unsaturated bond in the presence of said organotitanium reacting agent.

[Claim 13] The process as defined in Claim 11 or 12, wherein the reaction between a compound having an electrophilic functional group and a compound having a carbon-carbon unsaturated bond is followed by further addition of a compound having an electrophilic functional group.

[Claim 14] The process as defined in Claim 11, 12 or 13, wherein the reaction between a compound having an electrophilic functional group and a compound having a carbon-carbon unsaturated bond is followed by addition of an electrophilic reagent.

[Claim 15] The process for addition reaction as defined in Claim 11, wherein the compound having a carbon-carbon unsaturated bond and the compound having an electrophilic functional group are replaced by a compound having both a carbon-carbon unsaturated bond and an electrophilic functional group in the same molecule for intramolecular addition reaction.

[Claim 16] The process as defined in Claim 15, wherein the intramolecular addition reaction for a compound having a carbon-carbon unsaturated bond and an electrophilic functional group is followed by further addition of a compound having an electrophilic functional group.

[Claim 17] The process as defined in Claim 15 or 16, wherein the intramolecular addition reaction for a compound having a carbon-carbon unsaturated bond and an electrophilic functional group is followed by addition of an electrophilic reagent.

[Claim 18] The process defined in any of Claims 11 to 17, wherein the titanium compound is one which has an asymmetric ligand.

[Claim 19] The process as defined in any of Claims 11 to 18, wherein the compound having a carbon-carbon unsaturated bond is any of olefin compounds, acetylene compounds, or allene compounds.

[Claim 20] The process as defined in any of Claims 11 to 19, wherein the electrophilic functional group is an aldehyde group, ketone group, imino group, hydrazone group, aliphatic double bond, aliphatic triple bond, acyl group, ester group, or carbonate group.

[Claim 21] The process as defined in any of Claims 11, 12, 14, 17, 18, 19, and 20, wherein the electrophilic reagent is water, heavy water, chlorine, bromine, iodine, N-bromosuccimide, oxygen, carbon dioxide gas, or carbon monoxide.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Technical Field of the Invention]

The present invention relates to a new titanium catalyst and organotitanium reacting reagent, a process for their production, and a useful reaction by them.

[0002]

[Prior Art and the Problem to be Solved by the Invention]

Titanium compounds have been widely used for organic syntheses mostly in the form of Lewis acid catalyst or nucleophilic reagent in which the ligand is replaced by a nucleophilic reagent. The former is used for aldol reaction and Michael reaction (Mukaiyama et al., Angew. Chem., Int. Ed. Engl., 16, 817 (1977)) or for asymmetric ene reaction (Mikami et al., J. Am. Chem. Soc., 112, 3949

(1990)), and the latter is used for reaction of an organotitanium to be obtained from a titanium compound and an organolithium or Grignard reagent (Reetz et al., "Organotitanium Reagents in Organic Synthesis", Springer (1986)) or for reaction between an ester compound and a complex obtained from a titanium compound and an alkyl Grignard reagent (Corey et al., J. Am. Chem. Soc., 116, 9345 (1994)).

[0003]

The catalytic use of a titanium compound for the coupling reaction of less reactive molecules has been limited. (For example, the use of a low-valence titanium compound (obtained from a titanium compound and a reducing agent) for dimerization of a carbonyl compound (McMurry et al., Acc. Chem. Res., 7, 281 (1974)) and the use for the reaction that employs a Ziegler type reacting reagent obtained by combination of a titanium compound with a typical metal compound (Sato et al., Yuki Gosei Kagaku, 38, 234 (1980)).

[0004]

In contrast with titanium, zirconium (which also belongs to Group IVa) is an extremely useful metal catalyst for organic syntheses. For example, it functions as a divalent catalyst typified by zirconocene (biscyclopentadienyl zirconium) for the reaction of the carbon-carbon unsaturated bond, which has a comparatively low reactivity. (Negishi et al., Yuki Gosei Kagaku, 47, 2 (1989)). A few reactions by titanocene (as a titanium compound) are known; but they are seldom superior to those by zirconocene. (E. Negishi, Comprehensive Organic Synthesis, vol. 5, 1163-1184 (1991); B. M. Trost, I. Fleming, L. A. Paquette, Eds., Pergamon Press). Moreover, zirconocene and titanocene are too expensive for industrial use.

[0005]

It is an object of the present invention to provide a new titanium catalyst and organotitanium reacting reagent

to be used for reaction between a carbon-carbon unsaturated bond and a compound having an electrophilic functional group or an electrophilic reagent. It is another object of the present invention to provide a process for producing them. It is another object of the present invention to provide a process for addition reaction between a compound having a carbon-carbon unsaturated bond and a compound having an electrophilic functional group or an electrophilic reacting reagent, or for intramolecular addition reaction of a compound having both a carbon-carbon unsaturated bond and an electrophilic functional group in the same molecule.

[0006]

[Means for Solving the Problem and Embodiment of the Invention]

In order to achieve the above-mentioned object, the present inventors carried out a series of researches which led to the finding that when a compound (such as olefin compound, acetylene compound, and allene compound) having a carbon-carbon aliphatic or alicyclic unsaturated bond is reacted with a compound having an electrophilic functional group (such as aldehyde group, ketone group, imino group, hydrazone group, aliphatic or alicyclic double or triple bond, acyl group, ester group, and carbonate group) or with an electrophilic reagent in the presence of a titanium compound represented by the formula (1) below and a Grignard reagent represented by the formula (2) below (in a molar amount about 2 times as much as said titanium compound), the carbon-carbon aliphatic or alicyclic unsaturated bond (having a comparatively low reactivity) is activated, with the result that addition reaction between a compound having a carbon-carbon unsaturated bond and a compound having an electrophilic functional groups or a nucleophilic compound is catalyzed, and there is obtained an addition product of a compound having a carbon-carbon unsaturated bond with a compound having an electrophilic functional group or an electrophilic reagent. It was also

found that in the case where the reaction is applied to a compound having both a carbon-carbon aliphatic or alicyclic unsaturated bond and an electrophilic functional group in the same molecule, the intramolecular addition reaction advantageously proceeds.

[0007]

Incidentally, in J. Am. Chem. Soc., 116, 9345 (1994) mentioned above, Corey et al. reported the reaction which employs a titanium compound and an alkyl Grignard reagent as the reaction reagent. This combination is similar to that in the present invention; however, they use the alkyl group originating from the Grignard reagent as the nucleophilic reagent in their reaction. By contrast, the present invention employs as a catalyst the reaction products formed from the titanium compound and the alkyl Grignard reagent, thereby performing reaction on unsaturated compounds and electrophilic reagents. In other words, the present invention differs essentially from Corey's reaction in that the alkyl group originating from Grignard reagent is not used for reaction. Thus the present invention will find use in a broad range of applications.

[0008]

The present invention provides the following.

[i] A titanium catalyst for reaction between a carbon-carbon unsaturated bond and a compound having an electrophilic functional group or an electrophilic reagent, said titanium catalyst being composed of a titanium compound represented by the formula (1) below

$$TiX^1X^2X^3X^4 \qquad (1)$$

(where X^1, X^2, X^3, and X^4 denote independently a halogen atom, C1-20 alkoxyl group, aralkyloxy group, aryloxy group, or -NRxRy group (where Rx and Ry denote independently a C1-20 alkyl group or aralkyl group), and any two of X^1, X^2, X^3, and X^4 may form a ring.) and a Grignard reagent

represented by the formula (2) below in a molar amount 1-10 times as much as the titanium compound.

$$R^1MgX^5 \qquad (2)$$

(where R^1 denotes a C2-10 alkyl group having a hydrogen atom at the β position and X^5 denotes a halogen atom.)

[ii] A process for producing a titanium catalyst for reaction between a carbon-carbon unsaturated bond and a compound having an electrophilic functional group or an electrophilic reagent, said process comprising reacting a titanium compound represented by the formula (1) below

$$TiX^1X^2X^3X^4 \qquad (1)$$

(where X^1, X^2, X^3, and X^4 denote independently a halogen atom, C1-20 alkoxyl group, aralkyloxy group, aryloxy group, or -NRxRy group (where Rx and Ry denote independently a C1-20 alkyl group or aralkyl group), and any two of X^1, X^2, X^3, and X^4 may form a ring.) with a Grignard reagent represented by the formula (2) below in a molar amount 1-10 times as much as the titanium compound.

$$R^1MgX^5 \qquad (2)$$

(where R^1 denotes a C2-10 alkyl group having a hydrogen atom at the β position and X^5 denotes a halogen atom.)

[iii] An organotitanium reacting reagent which is composed of a titanium compound represented by the formula (1) below

$$TiX^1X^2X^3X^4 \qquad (1)$$

(where X^1, X^2, X^3, and X^4 denote independently a halogen atom, C1-20 alkoxyl group, aralkyloxy group, aryloxy group, or -NRxRy group (where Rx and Ry denote independently a C1-20 alkyl group or aralkyl group), and any two of X^1, X^2, X^3, and X^4 may form a ring.), a Grignard reagent represented by the formula (2) below in a molar amount 1-10 times as much as the titanium compound,

R^1MgX^5 (2)

(where R^1 denotes a C2-10 alkyl group having a hydrogen atom at the β position and X^5 denotes a halogen atom.), and a compound having a carbon-carbon unsaturated bond.

[iv] A process for producing an organotitanium reacting reagent, said process comprising reacting together a titanium compound represented by the formula (1) below

$TiX^1X^2X^3X^4$ (1)

(where X^1, X^2, X^3, and X^4 denote independently a halogen atom, C1-20 alkoxyl group, aralkyloxy group, aryloxy group, or -NRxRy group (where Rx and Ry denote independently a C1-20 alkyl group or aralkyl group), and any two of X^1, X^2, X^3, and X^4 may form a ring.), a Grignard reagent represented by the formula (2) below in a molar amount 1-10 times as much as the titanium compound,

R^1MgX^5 (2)

(where R^1 denotes a C2-10 alkyl group having a hydrogen atom at the β position and X^5 denotes a halogen atom.), and a compound having a carbon-carbon unsaturated bond.

[v] A process for addition reaction which comprises performing addition reaction on a compound having a carbon-carbon unsaturated bond and a compound having an electrophilic functional group or an electrophilic reagent, in the presence of a titanium compound represented by the formula (1) below

$TiX^1X^2X^3X^4$ (1)

(where X^1, X^2, X^3, and X^4 denote independently a halogen atom, C1-20 alkoxyl group, aralkyloxy group, aryloxy group, or -NRxRy group (where Rx and Ry denote independently a C1-20 alkyl group or aralkyl group), and any two of X^1, X^2, X^3, and X^4 may form a ring.) and a Grignard reagent represented by the formula (2) below in a molar amount 1-10 times as much as the titanium compound,

R^1MgX^5 (2)

(where R^1 denotes a C2-10 alkyl group having a hydrogen atom at the β position and X^5 denotes a halogen atom.)

[vi] A process for addition reaction as defined in [v] above wherein the compound having a carbon-carbon unsaturated bond and the compound having an electrophilic functional group are replaced by a compound having both a carbon-carbon unsaturated bond and an electrophilic functional group in the same molecule for intramolecular addition reaction.

[vii] A process for addition reaction which comprises adding a compound having an electrophilic functional group or an electrophilic reagent to an organotitanium reacting reagent which is obtained from a titanium compound represented by the formula (1) below

$TiX^1X^2X^3X^4$ (1)

(where X^1, X^2, X^3, and X^4 denote independently a halogen atom, C1-20 alkoxyl group, aralkyloxy group, aryloxy group, or -NRxRy group (where Rx and Ry denote independently a C1-20 alkyl group or aralkyl group), and any two of X^1, X^2, X^3, and X^4 may form a ring.), a Grignard reagent represented by the formula (2) below in a molar amount 1-10 times as much as the titanium compound,

R^1MgX^5 (2)

(where R^1 denotes a C2-10 alkyl group having a hydrogen atom at the β position and X^5 denotes a halogen atom.), and a compound having a carbon-carbon unsaturated bond, thereby performing addition reaction on said compound having a carbon-carbon unsaturated bond.

[0009]

The first aspect of the present invention resides in a titanium catalyst for reaction between a carbon-carbon unsaturated bond and a compound having an electrophilic functional group or an electrophilic reagent, said titanium

catalyst being composed of a titanium compound represented by the formula (1) below

$$TiX^1X^2X^3X^4 \quad (1)$$

(where X^1, X^2, X^3, and X^4 denote independently a halogen atom, C1-20 alkoxyl group, aralkyloxy group, aryloxy group, or -NRxRy group (where Rx and Ry denote independently a C1-20 alkyl group or aralkyl group), and any two of X^1, X^2, X^3, and X^4 may form a ring.) and a Grignard reagent represented by the formula (2) below in a molar amount 1-10 times as much as the titanium compound.

$$R^1MgX^5 \quad (2)$$

(where R^1 denotes a C2-10 alkyl group having a hydrogen atom at the β position and X^5 denotes a halogen atom.)

[0010]

The second aspect of the present invention resides in a process for producing a titanium catalyst by the reaction of a titanium compound represented by the formula (1) above with a Grignard reagent represented by the formula (2) above in a molar amount 1-10 times as much as the titanium compound.

[0011]

In formula (1), X^1, X^2, X^3, and X^4 denote independently a halogen atom, C1-20 alkoxyl group, aralkyloxy group, aryloxy group, or -NRxRy group (where Rx and Ry denote independently a C1-20 alkyl group or aralkyl group), and any two of X^1, X^2, X^3, and X^4 may form a ring.

[0012]

The halogen atom includes, for example, fluorine atom, chlorine atom, bromine atom, and iodine atom. The C1-20 alkoxyl group, aralkyloxy group, or aryloxy group includes, for example, methoxy, ethoxy, propoxy, i-propoxy, butoxy, i-butoxy, sec-butoxy, t-butoxy, hexyloxy, heptyloxy, octyloxy, nonyloxy, menthyloxy, benzyloxy, phenethyloxy, phenoxy, naphthyloxy, biphenyloxy, and binaphthyloxy. Rx and Ry include, for example, methyl,

ethyl, propyl, isopropyl, butyl, s-butyl, t-butyl, hexyl, cyclohexyl, heptyl, octyl, nonyl, benzyl, phenethyl, and naphthylethyl. The ring-forming group includes, for example, ethylenedioxy, propylenedioxy, 1,2-dimethyl-ethylenedioxy, tartrate diester dioxy, biphenyl-1,1'-dioxy, binaphthyl-1,1'-dioxy, and ethylene-1-amino-2-oxy, which form 5- to 7-membered rings by connection to a titanium atom through an oxygen or nitrogen atom. Preferred examples of the titanium compound represented by the formula (1) include tetraisopropoxytitanium, chlorotriiso-propoxytitanaium, and dichlorodipropoxytitanium.

[0013]

If the titanium compound has an asymmetric ligand, it yields an optically active compound through the asymmetric reaction with a nucleophilic group as mentioned later. The asymmetric ligand includes, for example, α-phenethyloxy, α-phenethylamino, menthyloxy, tartrate diester dioxy, biphenyldioxy, binaphthyldioxy, and 2-phenyl-ethylene-1-amino-2-oxy.

[0014]

In the formula (2), R^1 denotes a C2-10 alkyl group having a hydrogen atom at the β-position and X^5 denotes a halogen atom. The C2-10 alkyl group having a hydrogen atom at the β-position includes, for example, ethyl, propyl, i-propyl, butyl, i-butyl, sec-butyl, pentyl, i-pentyl, hexyl, i-hexyl, heptyl, i-heptyl, octyl, i-octyl, nonyl, i-nonyl, decyl, and i-decyl. The halogen atom includes, for example, chlorine atom, bromine atom, and iodine atom. Preferred examples of the Grignard reagent represented by the formula (2) include ethylmagnesium chloride, ethylmagnesium bromide, propylmagnesium chloride, propylmagnesium bromide, i-propylmagnesium chloride, and i-propylmagnesium bromide.

[0015]

According to the second aspect of the present invention, the titanium catalyst is prepared simply by

reacting in an inert solvent a titanium compound represented by the formula (1) with a Grignard reagent represented by the formula (2) in a molar amount of 1-10 times as much as the titanium compound. The inert solvent is not specifically restricted so long as it is not involved in the reaction. It includes, for example, saturated hydrocarbons (such as hexane and heptane), aromatic hydrocarbons (such as benzene and toluene), and ethers (such as diethyl ether, diisopropyl ether, t-butyl methyl ether, tetrahydrofuran, and dioxane). Preferred solvents include ethers, diethyl ether, diisopropyl ether, and t-butyl methyl ether. Reaction temperature should be -100 to 0°C, preferably -78 to -10°C. Reaction time should be 1 minute to 20 hours, preferably 10 minutes to 2 hours, depending on the reaction temperature. The equivalent amount of the Grignard reagent for the titanium compound should be 1-10, preferably 1.5-2.5, so that side reactions with the reaction substrate are avoided.

[0016]

The above-mentioned titanium catalyst composed of a titanium compound and a Grignard reagent is used for reaction between a carbon-carbon unsaturated bond and an electrophilic functional group. It is possible to add to the reaction system the titanium compound and Grignard reagent in the form of their reaction product prepared beforehand or separately such that they react in the reaction system. The latter procedure is simpler. The reaction system to which the titanium compound and Grignard reagent are added need not to contain both a compound having a carbon-carbon unsaturated bond and a compound having an electrophilic functional group or an electrophilic reagent. The reaction system will be satisfactory if it contains either of them, preferably the former.

[0017]

The third aspect of the present invention resides in an organotitanium reacting reagent which is composed of a

titanium compound represented by the formula (1) above, a Grignard reagent represented by the formula (2) above in a molar amount 1-10 times as much as the titanium compound, and a compound having a carbon-carbon unsaturated bond.

[0018]

The carbon-carbon unsaturated bond means an aliphatic or alicyclic double bond or triple bond, and the compound having such an unsaturated bond includes olefin compounds, acetylene compounds, and allene compounds.

The compound having a carbon-carbon unsaturated bond should be used in such an amount that the titanium catalyst (composed of the titanium compound and the Grignard reagent in a molar amount 1-10 times as much as the titanium compound) is 0.01-5 equivalent, preferably 0.5-1.2 equivalent, per equivalent of said compound.

[0019]

The organotitanium reacting reagent permits the compound having a carbon-carbon unsaturated bond to be involved in the addition reaction with a compound having an electrophilic functional group or with an electrophilic reagent.

[0020]

This organotitanium reacting reagent can be obtained from the above-mentioned titanium compound, Grignard reagent, and compound having a carbon-carbon unsaturated bond by mixing and reaction in an inert solvent. The inert solvent is not specifically restricted so long as it is not involved in the reaction. It includes, for example, saturated hydrocarbons (such as hexane and heptane), aromatic hydrocarbons (such as benzene and toluene), ethers (such as diethyl ether, diisopropyl ether, t-butyl methyl ether, tetrahydrofuran, and dioxane), and halogenated hydrocarbons (such as dichloromethane and dichloroethane), and mixtures thereof. Of these examples, ether solvents are preferable. The reaction temperature should be in the range of -100°C to the reflux temperature of the solvent, preferably -78 to 0°C. The reaction time should be 1

minute to 20 hours, preferably 10 minutes to 4 hours, depending on the reaction temperature.

[0021]

The above-mentioned titanium catalyst of the present invention activates the carbon-carbon unsaturated bond (aliphatic or alicyclic C-C double bond or C-C triple bond) and catalyzes the reaction of various nucleophilic functional groups and electrophilic reagents.

[0022]

Examples of the electrophilic functional group include aldehyde groups, ketone groups, imino groups, hydrazone groups, double bonds, triple bonds, acyl groups, ester groups, and carbonate groups. Examples of the compound include aldehyde compounds, ketone compounds, imine compounds, hydrazone compounds, olefin compounds, acetylene compounds, acyl compounds, ester compounds, α,β-unsaturated carbonyl compounds, and carbonate ester compounds. These functional groups may be present within the above-mentioned molecule having a carbon-carbon unsaturated bond. Examples of the electrophilic reagent include water, heavy water, chlorine, bromine, iodine, N-bromosuccimide, oxygen, carbon dioxide gas, and carbon monoxide.

[0023]

Presumably, the reaction forms as an intermediate the organotitanium reacting reagent from the titanium catalyst and the carbon-carbon unsaturated bond and the intermediate reacts with the electrophilic functional group or electrophilic reagent. In this case the reaction is carried out in an inert solvent. The inert solvent is not specifically restricted so long as it is not involved in the reaction. It includes, for example, saturated hydrocarbons (such as hexane and heptane), aromatic hydrocarbons (such as benzene and toluene), ethers (such as diethyl ether, diisopropyl ether, t-butyl methyl ether, tetrahydrofuran, and dioxane), and halogenated hydrocarbons (such as dichloromethane and dichloroethane), and mixtures

thereof. Ether solvents of the same type are desirable for the preparation of the titanium catalyst and the continuous operation. The reaction temperature should be in the range of -100°C to the reflux temperature of the solvent, preferably -78°C to 0°C. The reaction time should be 1 minute to 20 hours, preferably 10 minutes to 4 hours, depending on the reaction temperature. The amount of the electrophilic functional group compound should be 0.5-2 equivalents, preferably 0.7-1.3 equivalents, per equivalent of the carbon-carbon unsaturated bond compound, and the amount of the titanium catalyst should be 0.01-5 equivalents, preferably 0.5-1.2 equivalents, per equivalent of the carbon-carbon unsaturated bond compound. The reactants may be added in the following order.

· After catalyst preparation, the carbon-carbon unsaturated bond compound is added and then the electrophilic functional group compound or the electrophilic reagent is added.

· The catalyst is prepared in the presence of the carbon-carbon unsaturated bond compound and then the electrophilic functional group compound or the electrophilic reagent is added.

· The catalyst is added to a solution of the carbon-carbon unsaturated bond compound and the electrophilic functional group compound or the electrophilic reagent.

· Mixing together simultaneously all the reactants -- the titanium compound, the Grignard reagent, the carbon-carbon unsaturated bond compound, and the electrophilic functional group compound or the electrophilic reagent.

It is possible to add the reactants after catalyst preparation or to prepare the catalyst in the presence of the reactants also in the case where the carbon-carbon unsaturated bond and the electrophilic functional group are present in the same molecule. After the reaction with the electrophilic functional group compound, it is possible to suspend the reaction by adding an electrophilic reagent such as water.

[0024]

Typical reactions are shown below to explain the usefulness of the present invention. In the formulas below, Ra-Rk independently represent organic substituent groups such as hydrogen atom, substituted or unsubstituted linear or branched C1-20, especially C1-10, alkyl group, aralkyl group, alkenyl group, or alkynyl group, substituted or unsubstituted aromatic group, heterocyclic group, cycloalkane group, alkyl- or aromatic-substituted silyl group, alkyl- or aromatic- substituted tin group, and ester group.

[0025]

The C_{1-20} alkyl group includes methyl, ethyl, n-propyl, i-propyl, n-butyl, sec-butyl, t-butyl, pentyl, octyl, decyl, dodecyl, octadecyl, and eicosanyl.

The C_{7-17} aralkyl group includes benzyl, phenethyl, and α-methylbenzyl.

The C_{2-20} alkenyl group include vinyl, allyl, crotyl, decenyl, dodecenyl, octadecenyl, and eicosenyl.

The C_{2-20} alkynyl group includes ethynyl, hexynyl, decynyl, dodecynyl, octadecynyl, and eicosynyl.

The aromatic group includes phenyl, naphthyl, and anthranyl.

The heterocyclic group includes furyl, thiophenyl, and pyrazolyl.

The C_{3-10} cycloalkyl group includes cyclopropyl, cyclopentyl, cyclohexyl, cycloheptyl, and cyclodecyl.

[0026]

The substituted silyl group includes trimethyl silyl, triethyl silyl, tri-n-propylsilyl, tri-n-butylsilyl, t-butyldimethylsilyl, and tri-n-decylsilyl.

[0027]

The alkyl- or aromatic-substituted tin group include trimethyltin, triethyltin, tributyltin, triphenyltin, and tribenzyltin.

The ester group includes C_{2-11} ester groups such as methyl ester, ethyl ester, butyl ester, and decyl ester.

The above-mentioned C_{1-20} alkyl group, C_{7-17} aralkyl group, C_{2-20} alkenyl group, C_{2-20} alkynyl group, aromatic group, heterocyclic group, C_{3-10} cycloalkyl group, substituted silyl group, alkyl- or aromatic-substituted tin group, and ester group may have a substituent group such as halogen atom, C_{1-10} acyl group, C_{1-10} carbamate group, C_{1-10} ether group, C_{1-10} sulfonate ester group, C_{1-10} phosphate ester group, C_{7-17} aralkyl group, and C_{2-11} ester group.

[0028]

Examples are given below.

The olefin compound includes (substituted) halogenated allyl and (substituted) allyl alcohol derivatives.

The (substituted) halogenated allyl includes C_{1-20} alkyl-substituted halogenated allyl, phenyl-substituted halogenated allyl, o-halogenophenyl-substituted halogenated allyl, m-halogenophenyl-substituted halogenated allyl, and p-halogenophenyl-substituted halogenated allyl.

The (substituted) allyl alcohol derivative includes C_{4-13} allyl alcohol alkyl ester, C_{4-13} allyl alcohol alkyl carbamate, C_{4-13} allyl alcohol alkyl ether, C_{4-13} allyl alcohol alkylsulfonate ester, allyl alcohol-o-hydroxy-phenylsulfonate ester, allyl alcohol-m-hydroxylphenyl-sulfonate ester, allyl alcohol-p-hydroxyphenylsulfonate ester, and C_{4-13} allyl alcohol alkyl phosphate ester.

The above-mentioned allyl alcohol derivative may also have a substituent group such as C_{1-20} alkyl group, phenyl group, o-halogenophenyl group, m-halogenophenyl group, and p-halogenophenyl group.

[0029]

The acetylene compound includes (substituted) C_{2-20} compounds having a triple bond, (substituted) halogenated propargyl, (substituted) trialkyl (C_{3-12}) silylhalogenated propargyl, and (substituted) propargyl alcohol derivative.

The substituent group of the (substituted) C_{2-20} compound having a triple bond includes C_{1-20} alkyl group, phenyl group, o-halogenophenyl group, m-halogenophenyl

group, p-halogenophenyl group, and trialkyl (C_{3-12}) silyl group.

The (substituted) halogenated propargyl includes C_{1-20} alkyl-substituted halogenated propargyl, phenyl-substituted halogenated propargyl, o-halogenophenyl-substituted halogenated propargyl, m-halogenophenyl-substituted halogenated propargyl, p-halogenophenyl-substituted halogenated propargyl.

The (substituted) trialkyl (C_{3-12}) silylhalogenated propargyl includes trimethylsilyl halogenated propargyl, triethylsilyl halogenated propargyl, tri-n-propylsilyl halogenated propargyl, tri-n-butylsilyl halogenated propargyl, t-butyldimethylsilyl halogenated propargyl, and tri-n-decylsilyl halogenated propargyl.

The (substituted) propargyl alcohol derivative includes C_{4-13} propargyl alcohol alkyl ester, C_{4-13} propargyl alcohol alkyl carbamate, C_{4-13} propargyl alcohol alkyl ether, C_{4-13} propargyl alcohol alkylsulfonate ester, propargyl alcohol-o-hydroxyphenylsulfonate ester, propargyl alcohol-m-hydroxyphenylsulfonate ester, propargyl alcohol-p-hydroxyphenylsulfonate ester, and C_{4-13} propargyl alcohol alkyl phosphate ester.

The above-mentioned (C_{3-12}) silylhalogenated propargyl and propargyl alcohol derivative may be substituted further by any of C_{1-20} alkyl group, phenyl group, o-halogenophenyl group, m-halogenophenyl group, p-halogenophenyl group, and trialkyl (C_{3-12}) silyl group.

[0030]

The allene compound includes (substituted) halogenated allenyl and (substituted) allenyl alcohol derivatives.

The (substituted) halogenated allenyl includes C_{1-20} alkyl-substituted halogenated allenyl, C_{3-10} cycloalkyl-substituted halogenated allenyl, phenyl-substituted halogenated allenyl, o-halogenophenyl-substituted halogenated allenyl,

m-halogenophenyl-substituted halogenated allenyl, and p-halogenophenyl-substituted halogenated allenyl.

The (substituted) allenyl alcohol derivative includes C_{4-13} allenyl alcohol alkyl ester, C_{4-13} allenyl alcohol alkyl carbamate, C_{4-13} allenyl alcohol alkyl ether, C_{4-13} allenyl alcohol alkylsulfonate ester, allenyl alcohol-o-hydroxyphenylsulfonate ester, allenyl alcohol-mhydroxyphenylsulfonate ester, allenyl alcohol-p-hydroxyphenylsulfonate ester, and C_{4-13} allenyl alcohol alkyl phosphate ester.

The above-mentioned allenyl alcohol derivative may be substituted further by any of C_{1-20} alkyl group, phenyl group, o-halogenophenyl group, m-halogenophenyl group, and p-halogenophenyl group.

The above-mentioned halogen includes fluorine, chlorine, bromine, and iodine.

[0031]

The aldehyde compound includes C_{1-10} alkyl aldehyde, C_{4-14} cycloalkyl aldehyde, C_{2-14} cycloalkyl aldehyde, benzaldehyde, o-halogenobenzaldehyde, m-halogenobenzaldehyde, p-halogenobenzaldehyde, C_{1-10} alkyl ester-substituted phenylaldehyde, o-halogenosuccinic aldehyde, m-halogenosuccinic aldehyde, p-halogenosuccinic aldehyde, p-halogenobenzaldehyde, furylaldehyde, and thiophenealdehyde.

[0032]

The ketone compound includes C_{3-20} alkylketone, C_{4-30} alkyl ester-substituted alkylketone, C_{3-10} cycloalkylketone, acetophenone, tetralone, decalone, furylketone, and thiophenoketone.

The imine compound includes reaction products of the above-mentioned aldehyde compound and any of C_{1-10} alkylamine, aniline, and benzylamine.

The hydrazone compound includes reaction products of the above-mentioned ketone compound and C_{1-10} alkylhydrazine.

The olefin compound includes (substituted) allyl alcohol derivatives.

The (substituted) allyl alcohol derivative includes C_{4-13} allyl alcohol alkyl ester and C_{4-13} allyl alcohol alkyl carbamate.

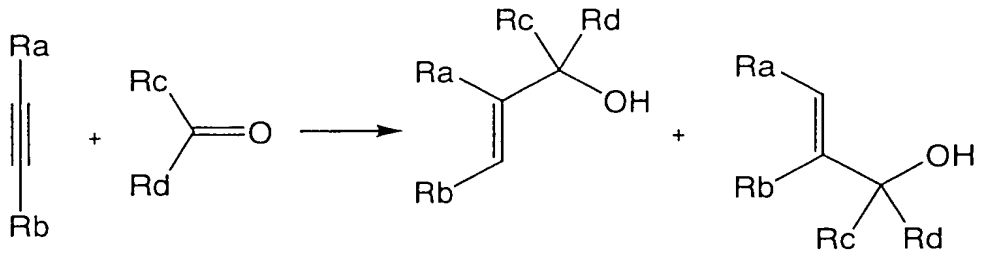
The above-mentioned allyl alcohol derivative may be substituted further by any of C_{1-20} alkyl group, phenyl group, o-halogenophenyl group, m-halogenophenyl group, and p-halogenophenyl group.

[0033]

I. Reaction between an acetylene compound and a compound containing an electrophilic functional group:

(1) Reaction between an acetylene compound and an aldehyde or ketone:

[0034]



A B

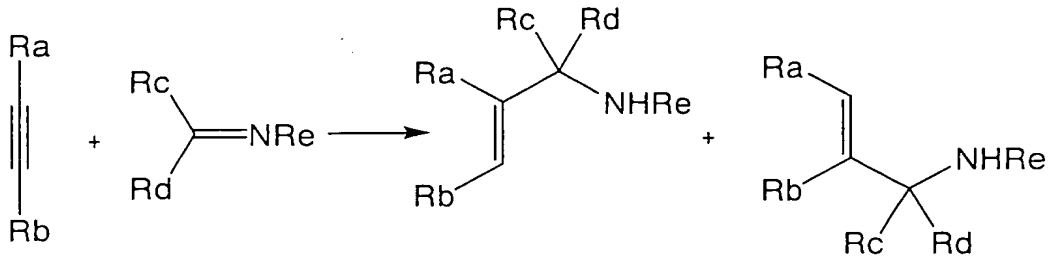
(where Ra, Rb, Rc, and Rd each denote an organic substituent group.)

[0035]

The reaction product is allyl alcohol (A) and/or (B) as an adduct. The double bond is situated in two different positions depending on the substituent group. The double bond takes on the cis-form for Ra and Rb.

(2) Reaction between an acetylene compound and an imine:

[0036]



C D

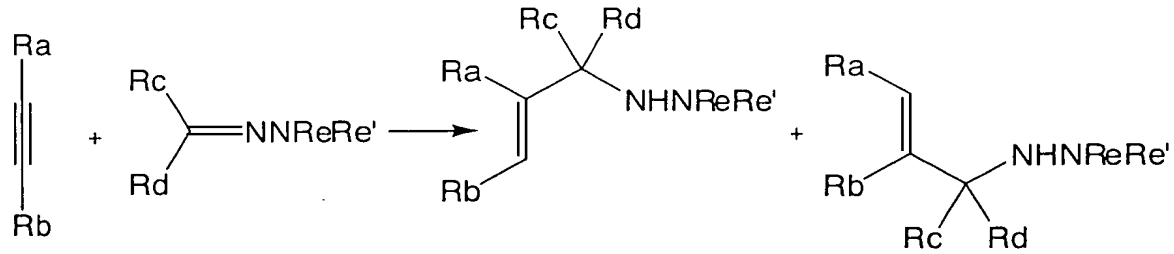
(where Ra, Rb, Rc, Rd, and Re each denote an organic substituent group; and Re may be metal such as lithium and magnesium.)

[0037]

The reaction product is allylamine (C) and/or (D) as an adduct.

(3) Reaction between an acetylene compound and a hydrazone compound:

[0038]



E F

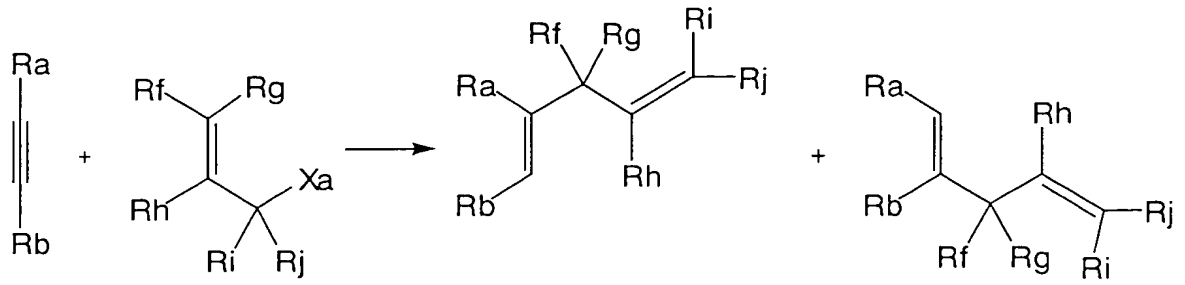
(where Ra, Rb, Rc, Rd, Re, and Re' each denote an organic substituent group.)

[0039]

The reaction product is hydrazine (E) and/or (F) as an adduct.

(4) Reaction between an acetylene compound and an allyl compound:

[0040]



G H

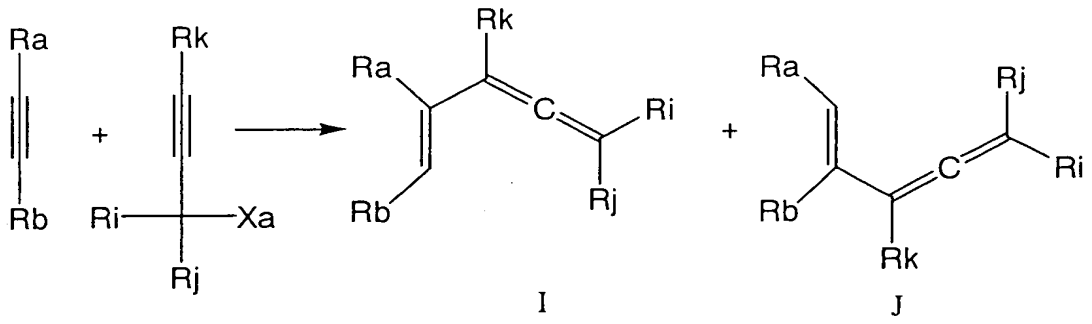
(where Ra, Rb, Rf, Rg, Rh, Ri, and Rj each denote an organic substituent group; and Xa denotes a halogen atom or a substituent hydroxyl group to be eliminated.)

[0041]

The reaction product is diene (G) and/or (H) as an adduct with Xa eliminated.

(5) Reaction between an acetylene compound and a propargyl compound:

[0042]



I J

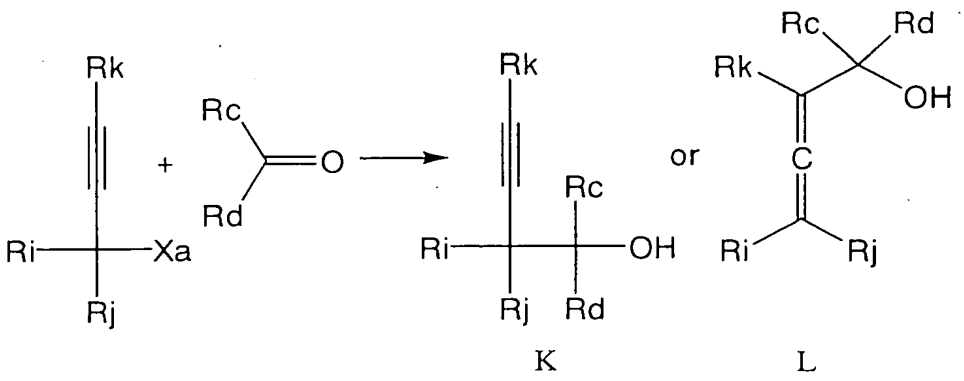
(where Ra, Rb, Rk, Ri, and Rj each denote an organic substituent group; and Xa denotes a halogen atom or a substituent hydroxyl group to be eliminated.)

[0043]

The reaction product is allene (I) and/or (J) as an adduct with Xa eliminated.

(6) Reaction between a propargyl compound and an aldehyde or ketone:

[0044]



(where Rk, Ri, Rj, Rc, and Rd each denote an organic substituent group; and Xa denotes a halogen atom or a substituent hydroxyl group.)

[0045]

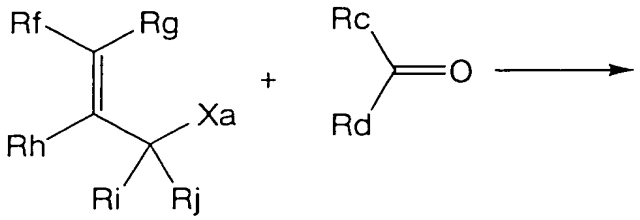
In the case where Rk is a hydrogen atom at the terminal of the acetylene compound, the reaction product is acetylene (K). In the case where Rk is an organic substituent group other than hydrogen atom, or in the case where both Rc and Rd are hydrogen atoms, the reaction product is allene (L) with Xa eliminated. In the case where either of Rc and Rd is not a hydrogen atom, the reaction product is acetylene (K).

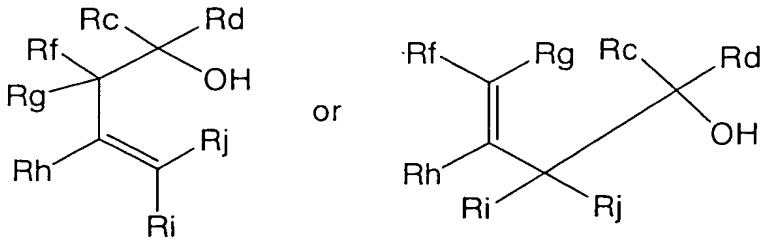
[0046]

II. Reaction between an olefin compound and a compound having an electrophilic functional group:

(1) Reaction between an allyl compound and an aldehyde or ketone:

[0047]





M N

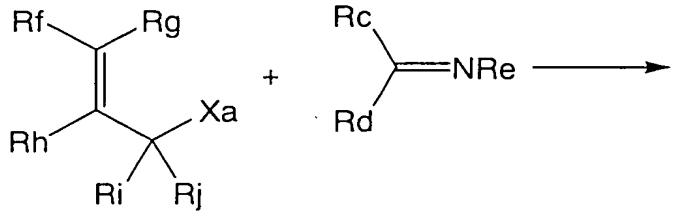
(where Rf, Rg, Rh, Ri, Rj, Rc, and Rd each denote an organic substituent group; and Xa denotes a halogen atom or a substituent hydroxyl group to be eliminated.)

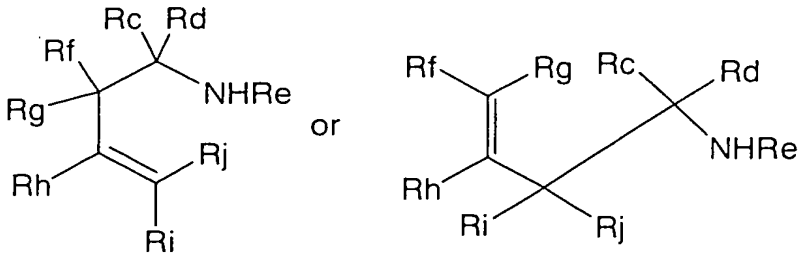
[0048]

The reaction product is alcohol (M) or (N) as an adduct with Xa eliminated.

(2) Reaction between an allyl compound and an imine compound:

[0049]





O P

(where Rf, Rg, Rh, Ri, Rj, Rc, Rd, and Re each denote an organic substituent group; and Xa denotes a halogen atom or a substituent hydroxyl group to be eliminated.)

[0050]

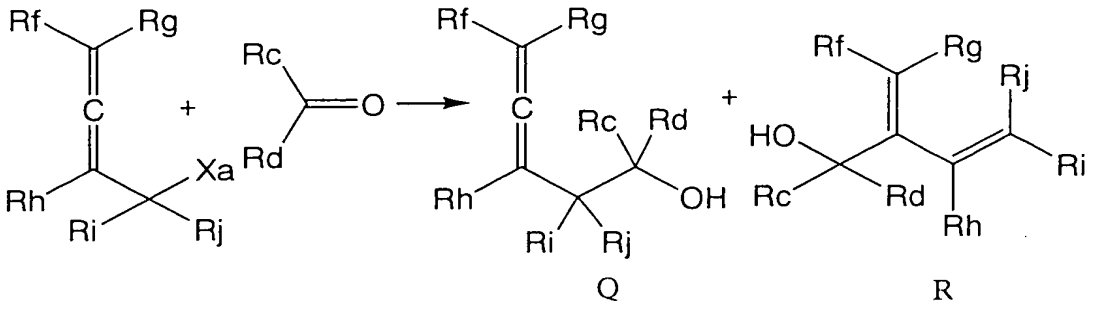
The reaction product is amine (O) or (P) as an adduct with Xa eliminated.

[0051]

III. Reaction between an allene compound and a compound having an electrophilic functional group:

(1) Reaction between an allene compound and an aldehyde or ketone:

[0052]



(where Rf, Rg, Rh, Ri, Rj, Rc, and Rd each denote an organic substituent group; and Xa denotes a halogen atom or a substituent hydroxyl group to be eliminated.)

[0053]

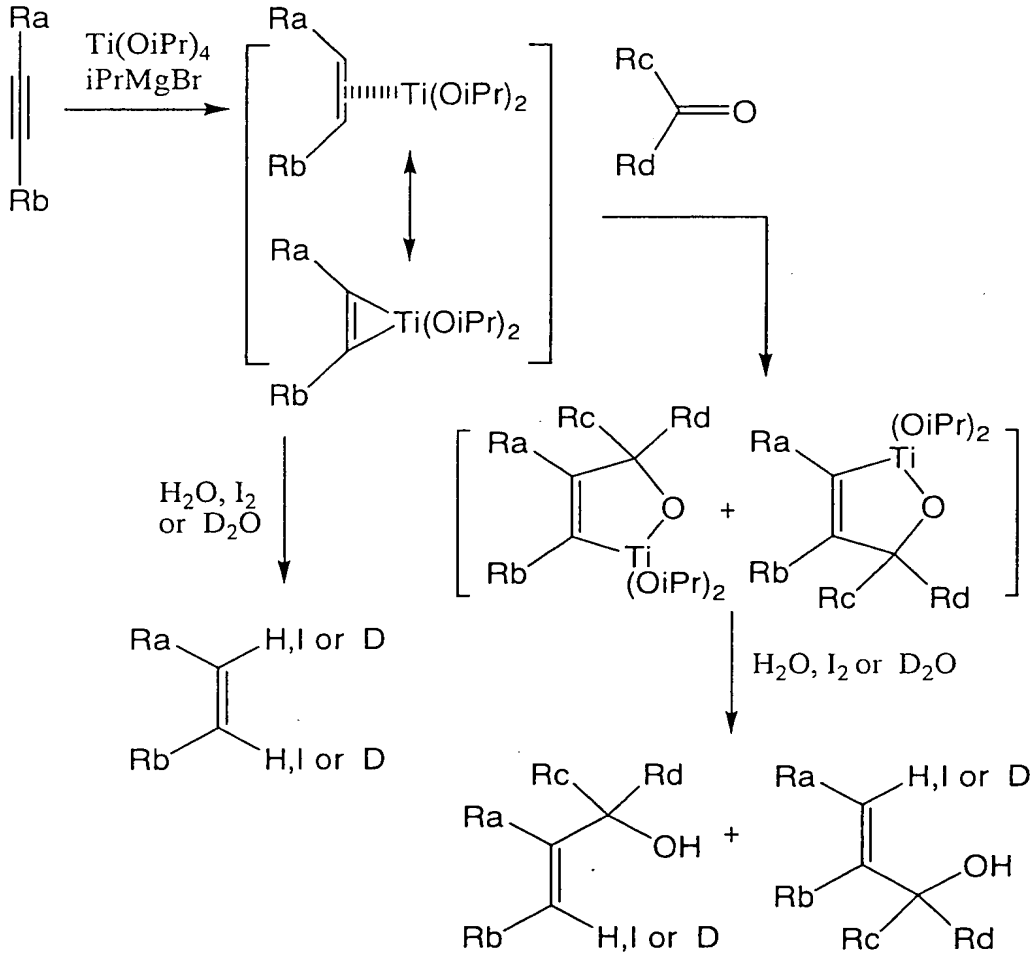
The reaction product is allene (Q) and/or diene (R) as an adduct with Xa eliminated.

[0054]

The above-mentioned reactions are followed by post-treatment which usually consists of adding water (as an electrophilic reagent) for replacement of the titanium group moiety by a hydrogen atom. If heavy water (D_2O) is added in place of water, there is obtained a compound having deuterium (D) in the molecule. If iodine is added, there is obtained a compound having iodine in the molecule. If water or heavy water (as an electrophilic reagent) is added in place of a compound having an electrophilic functional group, there is obtained a compound having a

hydrogen atom or deuterium atom in the molecule through cyclization of the unsaturated bond. For example, an acetylene compound undergoes the following reactions.

[0055]



[0056]

IV. Reaction of a compound having in the molecule both an unsaturated bond and an electrophilic functional group:

If in the above-mentioned reaction the titanium catalyst is acted on a compound having in the same molecule both an unsaturated bond and an electrophilic functional group, an intramolecular reaction takes place.

The compound having both an unsaturated bond and an electrophilic functional group may be one which has N, O, and S atoms in the carbon chain and also has a

(substituted) C_{1-5} alkylene group, (substituted) phenylene group, or heterocyclic group having an unsaturated bond at one end and an electrophilic functional group at the other end.

The above-mentioned alkylene group, phenylene group, and heterocyclic group may have a substituent group such as C_{1-10} alkyl group, phenyl group, hydroxyl group, hydroxyl group for protection of substituted silyl group, C_{8-15} aralkyloxyalkyl group, and C_{3-17} ester group-substituted alkyl group. The heterocyclic group includes pyrrole and indole.

The unsaturated bond includes C_{2-20} alkenyl group and C_{2-20} alkynyl group.

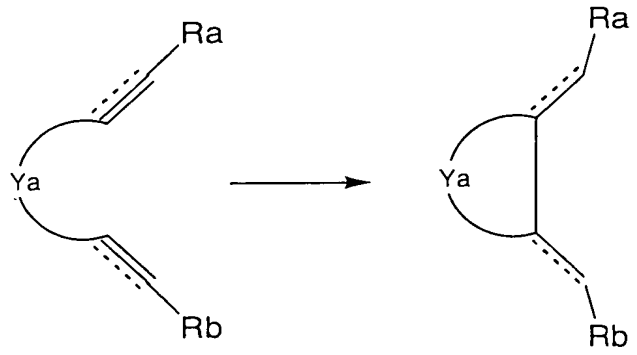
The above-mentioned C_{2-20} alkenyl group and C_{2-20} alkynyl group may have a substituent group such as C_{1-20} alkyl group, phenyl group, substituted silyl group, and alkyl or aromatic substituted tin group.

The functional group in the molecule includes double bond, triple bond, aldehyde group, ketone group, imino group, hydrazone group, C_{1-10} carbamate group, C_{1-10} acyl group, and C_{2-11} ester group.

Typical reaction types are given below.

(1) In the case of a compound having two non-conjugated double bonds:

[0057]



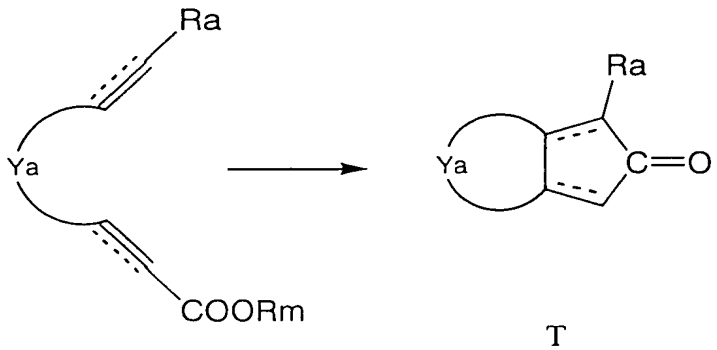
S

(where Ya denotes a substituted or unsubstituted alkylene group having 2-4 carbon atoms in the chain which may contain in the chain oxygen atoms, sulfur atoms, amino groups, or phenylene groups; ⩶ denotes a double bond or triple bond and ⎓ denotes a carbon-carbon single bond or double bond; and Ra and Rb are defined as above.)

[0058]

The reaction gives rise to the cyclic compound (S) as the result of cyclization between the unsaturated bonds in the molecule. In the case where Rb is an ester group, there is obtained a cyclic ketone (T) in which cyclization has proceeded further.

[0059]



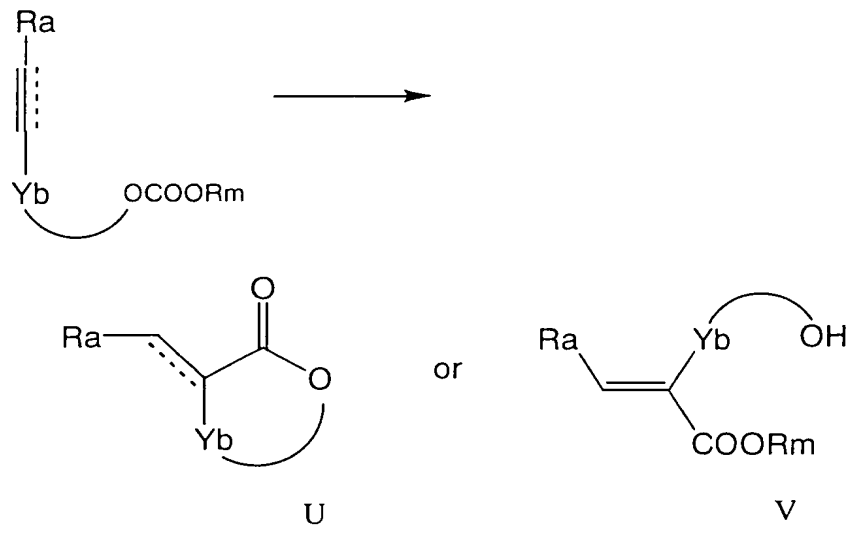
T

(where Ra, Ya, ⩶ , and ⎓ are defined as above; and Rm denotes a C1-10 alkyl group, aralkyl group, alkenyl group, or aryl group.)

[0060]

(2) In the case of a compound having an unsaturated bond and a carbonate group:

[0061]



U V

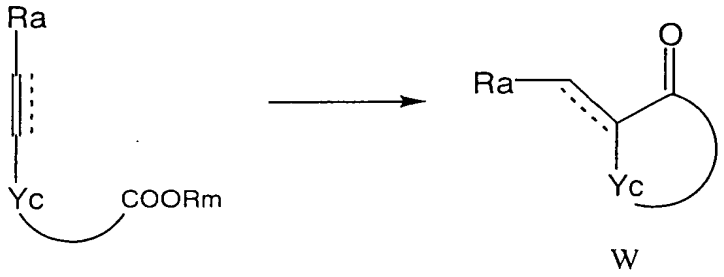
(where Yb denotes a substituted or unsubstituted alkylene group having 2-4 carbon atoms in the chain and ≡≡≡ , ---- , Ra, Rm defined as above.)

[0062]

The reaction gives rise to a lactone compound (U) through cyclization in the molecule or an α,β-unsaturated ester (V).

(3) In the case of a compound having both an unsaturated bond and an ester group:

[0063]



W

(where Yc denotes a substituted or unsubstituted alkylene group having 3-5 carbon atoms in the chain, and ≡≡≡ , ---- , Ra, Rm defined as above.)

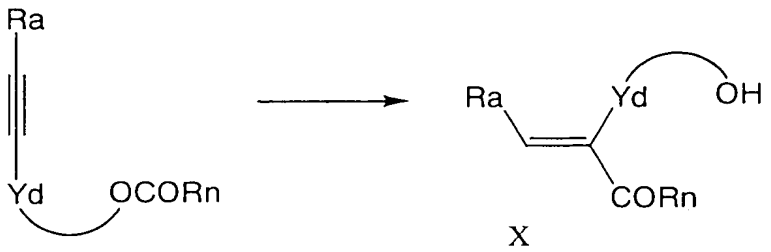
[0064]

The reaction gives rise to a cyclic ketone compound (W) through cyclization in the molecule.

(4) In the case of a compound having both an unsaturated bond and an acyl group:

(a) In the case of a compound having both a triple bond and an acyl group:

[0065]



X

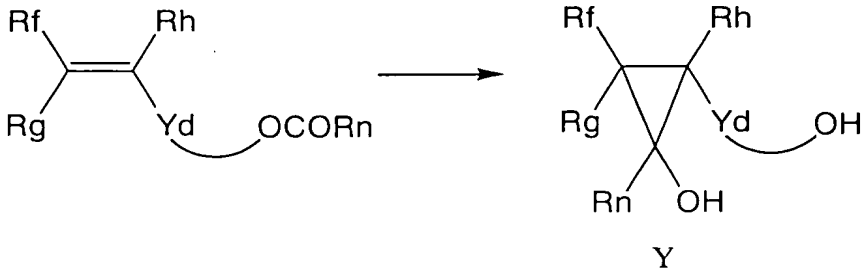
(where Yd denotes a substituted or unsubstituted alkylene group having 2-7 carbon atoms in the chain; Rn denotes a C1-10 alkyl group, alkenyl group, or substituted or unsubstituted phenyl group; and Ra is defined as above.)

[0066]

The reaction gives rise to an α,β-unsaturted ketone (X).

(b) In the case of a compound having both a double bond and an acyl group:

[0067]



Y

(where Rf, Rg, Rh, Ya, and Rn are defined as above.)

[0068]

The reaction gives rise to a cyclopropane compound (Y).

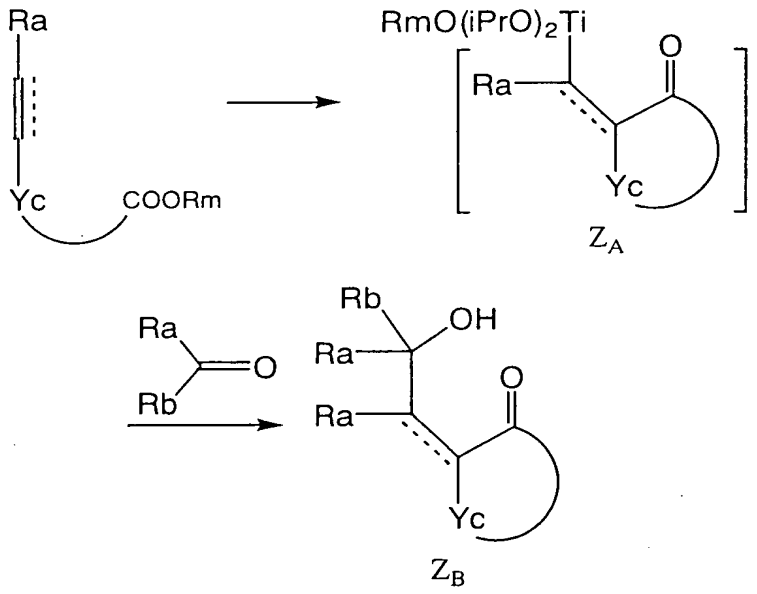
[0069]

V. Stepwise reaction

The above-mentioned reaction by the titanium catalyst between a compound having an unsaturated bond and

a compound having an electrophilic functional group or between an unsaturated bond and a compound having an electrophilic functional group may be followed by the adding of a compound having an electrophilic functional group in place of an electrophilic reagent (such as water). In this case there is obtained a compound resulting from the additional reaction of the compound having an electrophilic functional group on the titanium moiety. In other words, it is possible to carry out stepwise reactions. For example, in the case of IV-3, the additional reaction of aldehyde or ketone gives rise to a stepwise reaction product (Z_B) through an organic titanium intermediate (Z_A) as shown below.

[0070]



(where ═══ , ┅┅┅ , Ra, Rb, Yc, Rm defined as above.)

[0071]

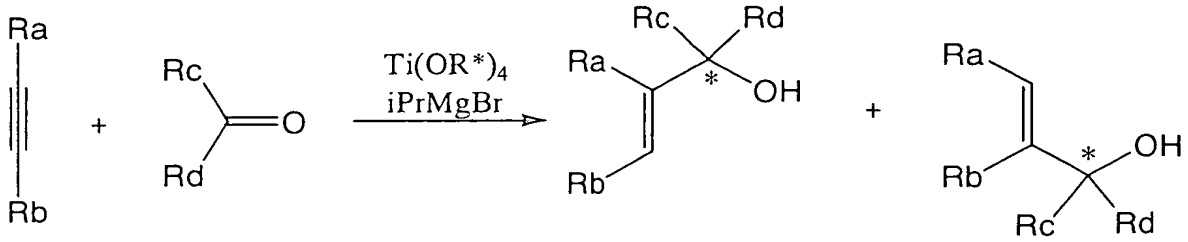
Furthermore, if the titanium compound is one which has an asymmetric ligand as mentioned above, the reaction with the electrophilic functional group is the asymmetric reaction which gives rise to an optically active compound.

[0072]

As a typical example, the reaction between an acetylene compound and an aldehyde or ketone that employs a

catalyst of titanium compound having an asymmetric ligand gives rises to optically active allyl alcohols (A*) and (B*).

[0073]



Rc=H : aldehyde A* B*

(where the asterisk (*) signifies the optical activity; Ra, Rb, Rc, and Rd are defined as above.)

[0074]

In addition to the above-mentioned various reaction types, there are further another intramolecular and intermolecular reaction types depending on the combination of the unsaturated compound and the electrophilic functional group. Therefore, the present invention is of great use.

[0075]

[Effect of the Invention]

According to the present invention, the titanium catalyst and the organotitanium reacting reagent activate the carbon-carbon unsaturated bond whose activity is comparatively low, thereby catalyzing the reaction with the electrophilic functional group. They are inexpensive and industrially advantageous. The titanium catalyst and the organotitanium reacting reagent bring about the reaction between the carbon-carbon unsaturated bond and the electrophilic functional group, so that they give rise to a variety of addition reaction products from a compound having a carbon-carbon unsaturated bond and a compound having an electrophilic functional group in an industrially advantageous manner or they give rise to a variety of intramolecular addition reaction products of compounds

having a carbon-carbon unsaturated bond and an electrophilic functional group in the same molecule.

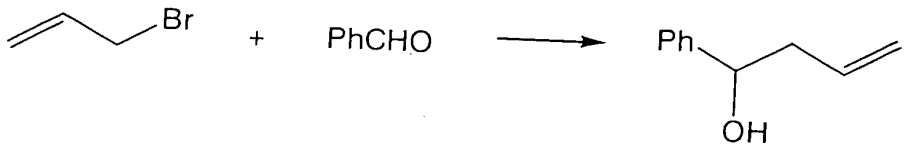
[0076]

[EXAMPLE]

The invention will be described in more detail with reference to the following examples, which are not intended to restrict the scope of the invention. In the examples, Me denotes a methyl group, Et denotes an ethyl group, i-Pr denotes an isopropyl group, Bu denotes a butyl group, ^{t}Bu denotes a t-butyl group, Ph denotes a phenyl group, Ac denotes an acetyl group, Ts denotes a p-toluenesulfonyl group, TMS denotes a trimethylsilyl group, and OEE denotes an ethoxyethyloxy group. Unless otherwise stated, ^{1}H-NMR means ^{1}H-NMR (300 MHz, $CDCl_3$, δ(ppm)), ^{13}C-NMR means ^{13}C-NMR (75 MHz, $CDCl_3$, δ(ppm)), and IR means IR (NEAT).

Example 1-1

[0077]



[0078]

To 0.30 ml (1.0 mmol) of tetraisopropoxytitanium and 5 ml of ethyl ether solution containing allyl bromide (1.0 mmol) was added dropwise at -50°C 1.67 ml of 1.2M ethyl ether solution containing isopropylmagnesium bromide (2.0 mmol). Upon stirring at -50 to -40°C for 1 hour, the reaction liquid turned from yellow into brown. To the reaction liquid was added 0.071 ml (0.7 mmol) of benzaldehyde at -45 to -40°C. The temperature was raised to -10 to 0°C over 30 minutes. With 5 ml of 1N hydrochloric acid added, the solution was heated to room temperature and separated into layers. The organic layer was washed with a saturated aqueous solution of sodium hydrogen carbonate. After drying with anhydrous magnesium sulfate, the solution was freed of solvent by vacuum

distillation. The residues were purified by silica gel chromatography. Thus there was obtained 97 mg of 1-phenyl-3-buten-1-ol (94% yields based on benzaldehyde).

[0079]

Examples 1-2 to 1-14

The procedure of Example 1-1 was repeated except that the allyl bromide, tetraisopropoxytitanium, and isopropylmagnesium bromide were replaced by those compounds shown in Table 1. There was obtained 1-phenyl-3-buten-1-ol in different yields as shown in Table 1.

[0080]

Table 1

Example	Allyl compound	Titanium compound	Grignard reagent	Yield of 1-phenyl-3-buten-1-ol (%)
1-1	X=Br	$Ti(O\text{-}i\text{-}Pr)_4$	i-PrMgBr	94
1-2	Br	$ClTi(O\text{-}i\text{-}Pr)_3$	i-PrMgBr	92
1-3	Br	$Cl_2Ti(O\text{-}i\text{-}Pr)_2$	i-PrMgBr	12
1-4	Br	$TiCl_4$	i-PrMgBr	20
1-5	Br	$Ti(O\text{-}i\text{-}Pr)_4$	i-PrMgCl	93
1-6	Br	$Ti(O\text{-}i\text{-}Pr)_4$	EtMgBr	72
1-7	Br	$Ti(O\text{-}i\text{-}Pr)_4$	n-PrMgBr	93
1-8	I	$Ti(O\text{-}i\text{-}Pr)_4$	i-PrMgBr	96
1-9	Cl	$Ti(O\text{-}i\text{-}Pr)_4$	i-PrMgBr	92
1-10	OAc	$Ti(O\text{-}i\text{-}Pr)_4$	i-PrMgBr	61
1-11	OC(O)OEt	$Ti(O\text{-}i\text{-}Pr)_4$	i-PrMgBr	74
1-12	OPh	$Ti(O\text{-}i\text{-}Pr)_4$	i-PrMgBr	89
1-13	OTs	$Ti(O\text{-}i\text{-}Pr)_4$	i-PrMgBr	57
1-14	$OP(O)(OEt)_2$	$Ti(O\text{-}i\text{-}Pr)_4$	i-PrMgBr	83

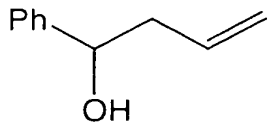
[0081]

Example 1-15

To 0.90 ml (3.0 mmol) of tetraisopropoxytitanium and 5 ml of n-butyl ether solution containing allyl bromide (3.0 mmol) was added dropwise at -78°C 6.2 ml of 0.97M n-butyl ether solution containing isopropylmagnesium bromide (6.0 mmol). After stirring at -50 to -40°C for 1 hour, the reaction liquid was given 0.21 ml (2.1 mmol) of benzaldehyde and heated to 0°C over 30 minutes. With 10 ml

of 3N hydrochloric acid added, the solution was heated to room temperature and separated into layers. The organic layer was washed with a saturated aqueous solution of sodium hydrogen carbonate. After drying with anhydrous magnesium sulfate, the solution was freed of solvent by vacuum distillation. The residues were purified by silica gel chromatography. Thus there was obtained 252 mg of 1-phenyl-3-buten-1-ol (81% yields based on benzaldehyde).

[0082]



[0083]

^{1}H-NMR, δ: 2.42-2.51 (m, 2H)
2.56 (br s, 1H)
4.63 (t, J=6.4 Hz, 1H)
5.04-5.19 (m, 2H)
5.67-5.84 (m, 1H)
7.18-7.39 (m, 5H)

^{13}C-NMR, δ: 43.7, 73.3, 118.2, 125.8, 127.4, 128.3, 134.4, 143.8

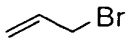
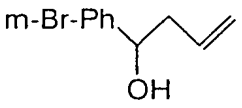
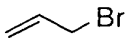
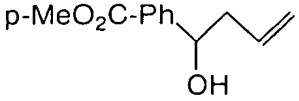
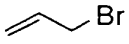
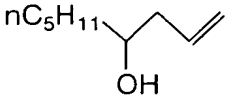
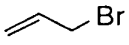
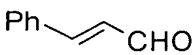
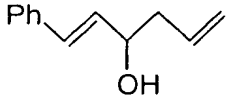
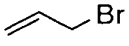
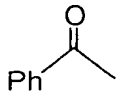
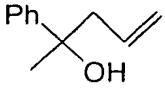
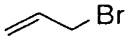
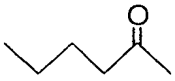
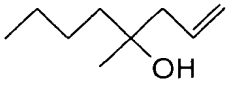
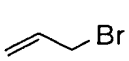
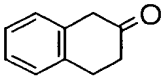
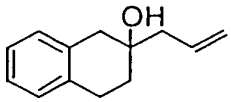
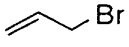
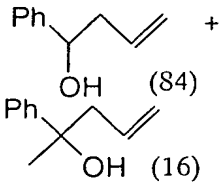
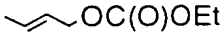
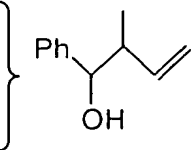
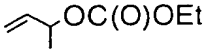
[0084]

Examples 2-1 to 2-17

The procedure of Example 1-1 was repeated except that the allyl bromide and benzaldehyde were replaced by those compounds shown in Tables 2 and 3. There were obtained corresponding allyl alcohols in yields as shown in Tables 2 and 3.

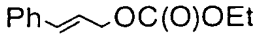
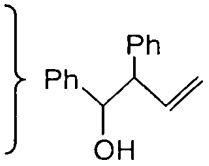
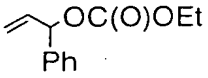
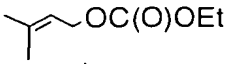
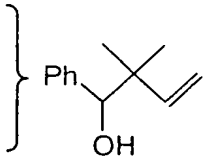
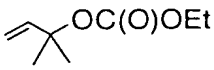
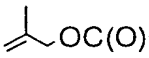
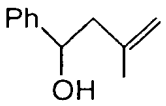
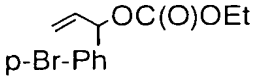
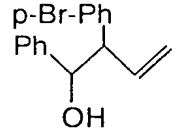
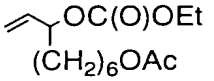
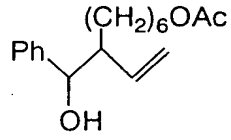
[0085]

Table 2

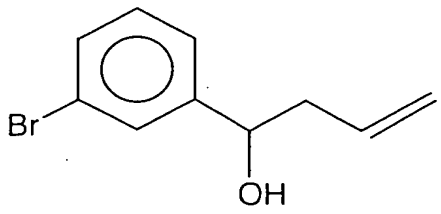
Example	Allyl compound	Aldehyde or ketone	Reaction product	Yield (%), (anti : syn)
2-1		m-Br-PhCHO		80
2-2		p-MeO_2C-PhCHO		77
2-3		n-$C_5H_{11}CHO$		87
2-4				88
2-5				85
2-6				82
2-7				92
2-8		PhCHO + 		91
2-9		PhCHO		50(75:25)
2-10		PhCHO		74(75:25)

[0086]

Table 3

Example	Allyl compound	Aldehyde or ketone	Reaction product	Yield (%), (anti : syn)
2-11		PhCHO		23(>97:3)
2-12		PhCHO		73(>97:3)
2-13		PhCHO		12
2-14		PhCHO		56
2-15		PhCHO		84
2-16		PhCHO		83(>97:3)
2-17		PhCHO		78(77:23)

[0087]

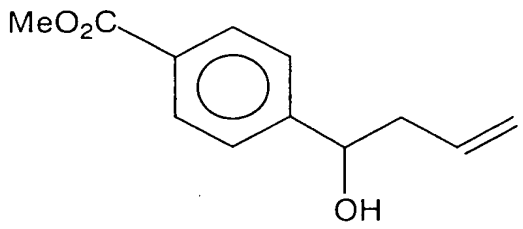


[0088]

^{1}H-NMR, δ: 2.22 (br s, 1H)
2.35-2.56 (m, 2H)
4.67 (t, J=6.4 Hz, 1H)
5.09-5.20 (m, 2H)
5.68-5.85 (m, 1H)
7.15-7.28 (m, 2H)
7.39 (dt, J=7.5, 1.7 Hz, 1H)
7.50 (s, 1H)

^{13}C-NMR, δ: 43.7, 72.4, 118.9, 122.5, 124.4, 128.9, 129.9, 130.5, 133.8, 146.1

[0089]

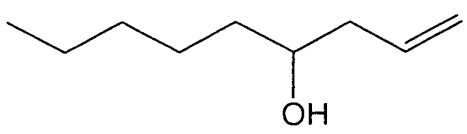


[0090]

^{1}H-NMR, δ: 2.39-2.55 (m, 2H)
2.99 (br s, 1H)
3.87 (s, 3H)
4.75 (t, J=6.5 Hz, 1H)
5.06-5.15 (m, 2H)
5.67-5.83 (m, 1H)
7.38 (d, J=8.4 Hz, 2H)
7.95 (d, J=8.4 Hz, 2H)

^{13}C-NMR, δ: 43.5, 51.9, 72.7, 118.4, 125.6, 128.9, 129.5, 133.8, 149.1, 166.9

[0091]

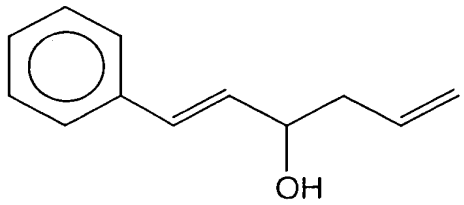


[0092]

^{1}H-NMR, δ: 0.88 (t, J=6.6 Hz, 3H)
1.18-1.52 (m, 8H)
1.72 (br s, 1H)
2.05-2.35 (m, 2H)
3.57-3.68 (m, 1H)
5.07-5.17 (m, 2H)
5.74-5.89 (m, 1H)

^{13}C-NMR, δ: 14.0, 22.6, 25.3, 31.8, 36.7, 41.9, 70.7, 117.9, 134.9

[0093]

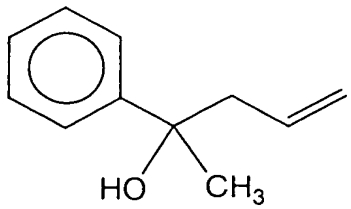


[0094]

^{1}H-NMR, δ: 1.93 (br s, 1H)
2.32-2.50 (m, 2H)
4.35 (ddt, J=1.0, 6.3, 5.6 Hz, 1H)
5.12-5.23 (m, 2H)
5.77-5.93 (m, 1H)
6.23 (dd, J=6.3, 15.9 Hz, 1H)
6.60 (dd, J=1.0, 15.9 Hz, 1H)
7.19-7.40 (m, 5H)

^{13}C-NMR, δ: 41.9, 71.7, 118.4, 126.4, 127.6, 128.5, 130.3, 131.5, 134.0, 136.6

[0095]



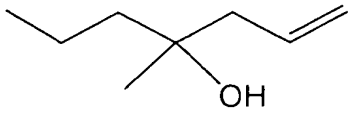
[0096]

^{1}H-NMR, δ: 1.53 (s, 3H)
2.22 (br s, 1H)

2.48 (dd, J=8.3, 13.7 Hz, 1H)
2.67 (dd, J=6.5, 13.7 Hz, 1H)
5.06-5.15 (m, 2H)
5.53-5.68 (m, 1H)
7.16-7.46 (m, 5H)

^{13}C-NMR, δ: 29.7, 48.4, 73.6, 119.3, 124.7, 126.5, 128.1, 133.6, 147.5

[0097]

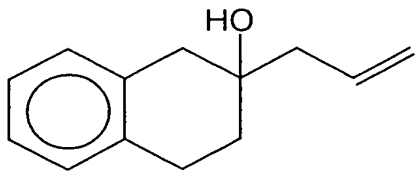


[0098]

^{1}H-NMR, δ: 0.89 (t, J=7.0 Hz, 3H)
1.14 (s, 3H)
1.20-1.48 (m, 6H)
1.61 (br s, 1H)
2.20 (d, J=7.1 Hz, 2H)
5.04-5.14 (m, 2H)
5.76-5.93 (m, 1H)

^{13}C-NMR, δ: 14.0, 23.2, 26.0, 26.6, 41.5, 46.2, 72.1, 118.4, 134.1

[0099]

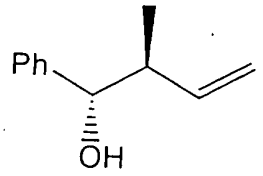


[0100]

^{1}H-NMR, δ: 1.67-1.87 (m, 2H)
1.96 (br s, 1H)
2.28 (d, J=7.4 Hz, 2H)
2.66-3.03 (m, 4H)
5.06-5.19 (m, 2H)
5.84-6.01 (m, 1H)
6.96-7.20 (m, 4H)

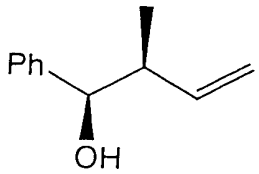
^{13}C-NMR, δ: 26.0, 33.5, 41.5, 45.5, 70.3, 118.8, 125.7, 125.8, 128.5, 129.4, 133.3, 134.3, 135.3

[0101]



threo

+



erythro

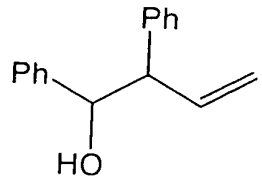
(threo-major) 80:20

[0102]

^{1}H-NMR, δ: 0.87 (d, J=6.8 Hz, 2H)
1.01 (d, J=6.8 Hz, 2H)
2.42-2.54 (m, 1H)
2.52-2.64 (m, 1H)
4.36 (d, J=7.9 Hz, 1H)
4.62 (d, J=5.5 Hz, 1H)
5.01-5.26 (m, 2H)
5.69-5.89 (m, 1H)
7.22-7.45 (m, 5H)

^{13}C-NMR, δ: (threo) 16.4, 46.1, 77.8, 116.6, 126.8, 127.5, 128.1, 140.6, 142.4
(erythro) 14.0, 44.6, 77.2, 115.4, 126.5, 127.2, 128.0, 140.3, 142.5

[0103]

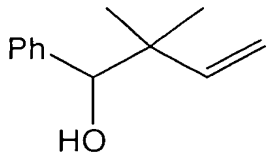


[0104]

^{1}H-NMR, δ: 2.37 (br s, 1H)
3.48-3.58 (m, 1H)
4.82 (d, J=4.5 Hz, 1H)
5.15-5.28 (m, 2H)
6.16-6.31 (m, 1H)
6.98-7.37 (m, 10H)

^{13}C-NMR, δ: 58.9, 76.8, 118.1, 126.3, 126.4, 127.1, 127.6, 128.1, 137.6, 140.4, 141.6

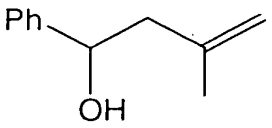
[0105]



[0106]

^{1}H-NMR, δ: 0.96 and 1.01 (2s, 6H)
2.08 (br s, 1H)
4.41 (s, 1H)
5.08 (d, J=19.5 Hz, 1H)
5.13 (d, J=16.5 Hz, 1H)
5.92 (dd, J=16.5, 19.5 Hz, 1H)
7.20-7.40 (m, 5H)

[0107]

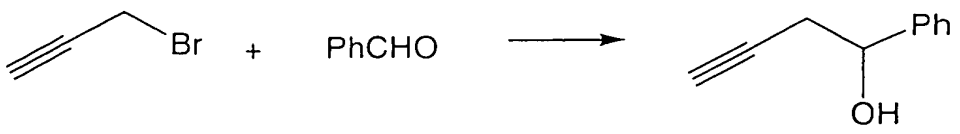


[0108]

^{1}H-NMR, δ: 1.78 (s, 3H)
2.21 (br s, 1H)
2.41 (d, J=4.5 Hz, 2H)
4.79 (t, J=4.5 Hz, 1H)
4.84 and 4.91 (2br s, 2H)
7.22-7.40 (m, 5H)
^{13}C-NMR, δ: 22.3, 48.1, 71.5, 113.8, 125.7, 127.3, 128.2, 142.2, 144.0

Example 3-1

[0109]



[0110]

To 0.425 ml (1.43 mmol) of tetraisopropoxytitanium and 10 ml of ethyl ether solution of propargyl bromide (0.127 ml, 1.43 mmol) was added dropwise at -50°C 1.90 ml of 1.43M ethyl ether solution containing isopropylmagnesium

bromide (2.72 mmol). After stirring at -50 to -40°C for 1 hour, the reaction liquid was given 0.102 ml (1.0 mmol) of benzaldehyde at -40°C and heated to -20°C over 30 minutes. With 1N hydrochloric acid added, the solution was heated to room temperature and separated into layers. The organic layer was washed with a saturated aqueous solution of sodium hydrogen carbonate. After drying with anhydrous magnesium sulfate, the solution was freed of solvent by vacuum distillation. The residues were purified by silica gel chromatography. Thus there was obtained 124 mg of 4-phenyl-1-butyn-4-ol (85% yields based on benzaldehyde).

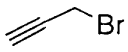
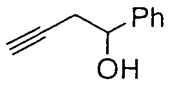
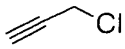
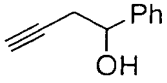
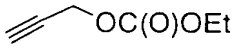
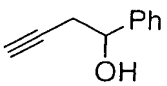
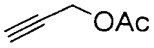
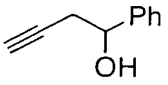
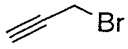
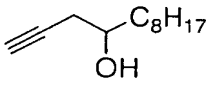
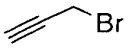
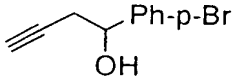
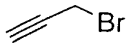
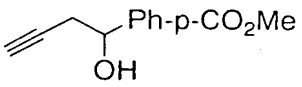
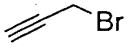
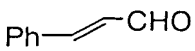
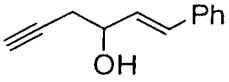
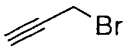
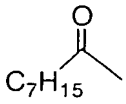
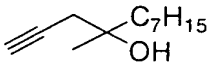
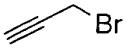
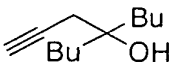
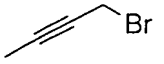
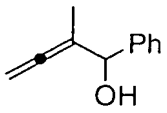
[0111]

Examples 3-2 to 3-21

The procedure of Example 3-1 was repeated except that the propargyl bromide and benzaldehyde were replaced by those compounds shown in Tables 4 and 5. There were obtained corresponding alcohols in yields as shown in Tables 4 and 5.

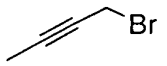
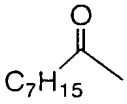
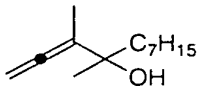
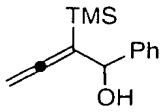
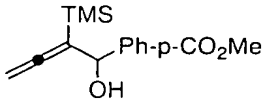
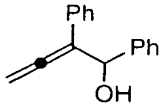
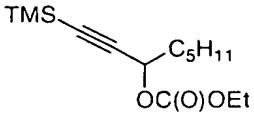
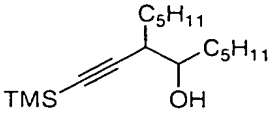
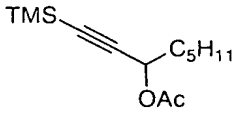
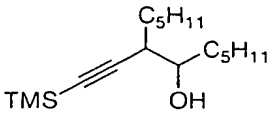
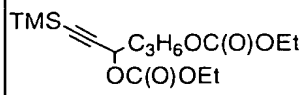
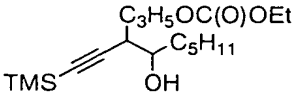
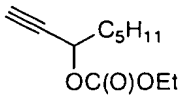
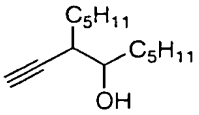
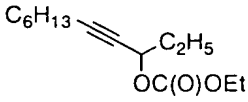
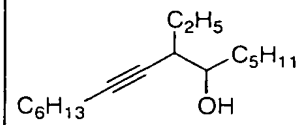
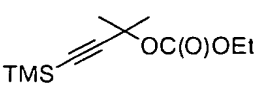
[0112]

Table 4

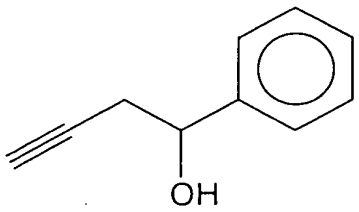
Example	Propargyl compound	Aldehyde	Reaction product	Yield (%), (anti : syn)
3-1		PhCHO		85
3-2		PhCHO		82
3-3		PhCHO		74
3-4		PhCHO		36
3-5		$C_8H_{17}CHO$		91
3-6		p-BrPhCHO		91
3-7		p-MeO_2CPhCHO		86
3-8				74
3-9				85
3-10		BuC(O)Bu		78
3-11		PhCHO		89

[0113]

Table 5

Example	Propargyl compound	Aldehyde	Reaction product	Yield (%), (anti : syn)
3-12				83
3-13		PhCHO		83
3-14		p-MeO_2CPhCHO		79
3-15		PhCHO		86
3-16		C_5H_{11}CHO		70(80:20)
3-17		C_5H_{11}CHO		77(80:20)
3-18		C_5H_{11}CHO		88(76:24)
3-19		C_5H_{11}CHO		89(75:25)
3-20		C_5H_{11}CHO		89(72:28)
3-21		PhCHO		78

[0114]



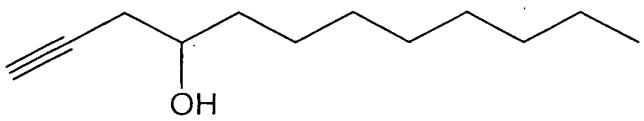
[0115]

^{1}H-NMR, δ: 2.06 (t, J=2.6 Hz, 1H)
2.62 (dd, J=2.6 Hz, 6.4 Hz, 2H)
4.84 (t, J=6.3 Hz, 1H)
7.2-7.4 (m, 5H)

^{13}C-NMR, δ: 29.3, 70.9, 72.2, 80.6, 125.7, 127.9, 128.4, 142.4

IR: 695, 750, 855, 1045, 1245, 1450, 1495, 1600, 1710, 1945, 2110, 2915, 3280, 3350 (cm^{-1})

[0116]



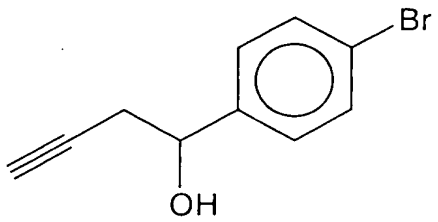
[0117]

^{1}H-NMR, δ: 0.85 (t, J=6.7 Hz, 3H)
1.1-1.4 (m, 12H)
1.50 (t, J=6.8 Hz, 2H)
2.02 (t, J=2.6 Hz, 1H)
2.20 (bs, 1H)
2.34 (m, 2H)
3.72 (quinted, J=6.0 Hz, 1H)

^{13}C-NMR, δ: 14.0, 22.6, 25.5, 27.6, 29.2, 29.5, 31.8, 36.2, 69.8, 70.6, 80.9

IR: 845, 1065, 1120, 1250, 1455, 1710, 2115, 2850, 2890, 3295, 3340 (cm^{-1})

[0118]



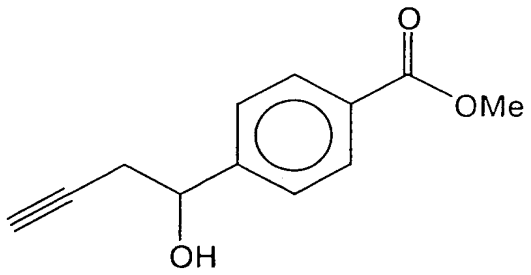
[0119]

^{1}H-NMR, δ: 2.07 (t, J=2.6 Hz, 1H)
2.59 (dd, J=2.6 Hz, 6.6 Hz, 2H)
2.73 (bs, 1H)
4.80 (t, J=6.3 Hz, 1H)
7.24 (d, J=8.7 Hz, 2H)
7.47 (d, J=8.5 Hz, 2H)

^{13}C-NMR, δ: 29.3, 71.4, 80.1, 121.7, 127.4, 131.5, 141.3

IR: 760, 820, 1005, 1055, 1190, 1255, 1400, 1485, 1590, 1700, 1745, 2100, 2880, 3275, 3360 (cm^{-1})

[0120]



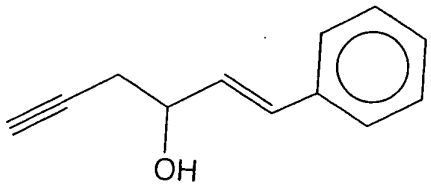
[0121]

^{1}H-NMR, δ: 2.07 (t, J=2.6 Hz, 1H)
2.64 (dd, J=1.6 Hz, 6.8 Hz, 2H)
3.00 (bs, 1H), 3.89 (s, 3H)
4.91 (bs, 1H)
7.45 (d, J=8.3 Hz)
7.99 (d, J=8.2 Hz)

^{13}C-NMR, δ: 29.3, 52.0, 71.3, 71.7, 80.0, 125.7, 129.6, 147.5, 166.8

IR: 700, 765, 855, 960, 1015, 1055, 1105, 1180, 1265, 1440, 1570, 1615, 1710, 1930, 2120, 2920, 3280, 3410 (cm^{-1})

[0122]



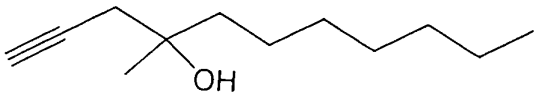
[0123]

^{1}H-NMR, δ: 2.08 (t, J=2.7 Hz, 1H)
2.54 (ddd, J=2.1 Hz, 3.0 Hz, 5.8 Hz, 2H)
2.69 (bs, 1H)
4.45 (q, J=6.1 Hz, 1H)
6.27 (dd, J=6.3 Hz, 15.9 Hz, 1H)
6.64 (d, J=15.9 Hz, 1H)

^{13}C-NMR, δ: 27.6, 70.6, 71.0, 80.2, 126.5, 127.8, 128.5, 129.9, 131.2, 136.3

IR: 690, 750, 850, 970, 1035, 1100, 1265, 1420, 1450, 1500, 1600, 1710, 2130, 2810, 3025, 3290, 3370 (cm^{-1})

[0124]



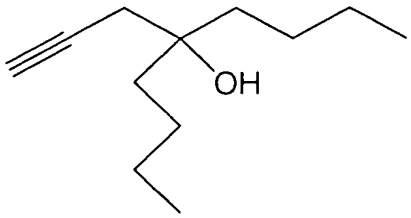
[0125]

^{1}H-NMR, δ: 0.85 (t, J=6.7 Hz, 3H)
1.26 (s, 3H)
1.2-1.4 (m, 10H)
1.49-1.59 (m, 2H)
1.94 (bs, 1H)
2.04 (t, J=2.7 Hz, 1H)
2.33 (d, J=1.5 Hz, 2H)

^{13}C-NMR, δ: 14.0, 22.6, 23.9, 26.2, 29.2, 30.0, 31.7, 32.3, 41.1, 71.1, 71.6, 80.9

IR: 775, 910, 950, 1050, 1270, 1385, 1470, 1720, 2140, 2870, 2925, 3315, 3365 (cm^{-1})

[0126]



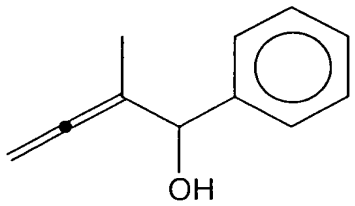
[0127]

^{1}H-NMR, δ: 1.14 (t, J=6.8 Hz, 6H)
1.2-1.4 (m, 8H)
1.4-1.6 (m, 4H)
1.81 (bs, 1H)
2.01 (t, J=2.7 Hz, 1H)
2.31 (d, J=2.6 Hz, 2H)

^{13}C-NMR, δ:13.9, 23.1, 25.6, 30.1, 38.3, 70.9, 73.3, 80.8

IR: 845, 1005, 1135, 1260, 1385, 1455, 1715, 1750, 2120, 2865, 2970, 3300, 3400 (cm^{-1})

[0128]



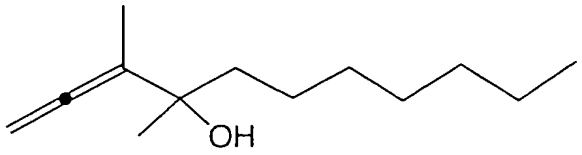
[0129]

^{1}H-NMR, δ: 1.55 (t, J=3.1 Hz, 3H)
2.49 (d, J=3.8 Hz, 1H)
4.87 (m, 2H)
5.07 (bs, 1H)
7.2-7.4 (m, 5H)

^{13}C-NMR, δ: 14.4, 74.6, 77.5, 102.5, 126.4, 127.6, 128.2, 141.8, 204.8

IR: 695, 730, 845, 1015, 1165, 1365, 1440, 1495, 1595, 1955, 2910, 3340 (cm^{-1})

[0130]



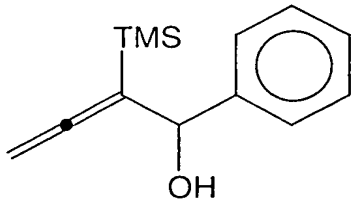
[0131]

^{1}H-NMR, δ: 0.86 (t, J=6.7 Hz, 3H)
1.20-1.31 (m, 10H)
1.28 (s, 3H)
1.49-1.59 (m, 2H)
1.69 (t, J=3.2 Hz)
1.79 (bs, 1H)
4.76 (q, J=3.1 Hz)

^{13}C-NMR, δ: 14.1, 14.6, 22.7, 24.0, 27.1, 29.3, 30.0, 31.9, 40.4, 77.0, 105.8, 204.4

IR: 845, 925, 1090, 1125, 1255, 1375, 1455, 1705, 1955, 2865, 2920, 3345 (cm^{-1})

[0132]



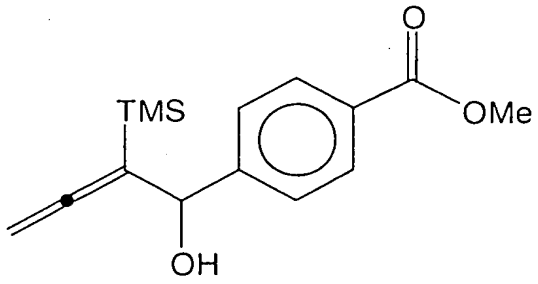
[0133]

^{1}H-NMR, δ: 0.20 (s, 9H)
2.72 (d, J=4.4 Hz, 1H)
4.86 (dd, J=1.9 Hz, 2.8 Hz, 2H)
5.44 (bs, 1H)
7.4-7.6 (m, 5H)

^{13}C-NMR, δ: -1.18, 72.6, 72.8, 101.2, 126.8, 127.6, 128.1, 143.0, 207.0

IR: 705, 755, 845, 1050, 1200, 1255, 1410, 1460, 1500, 1605, 1935, 2960, 3370 (cm^{-1})

[0134]



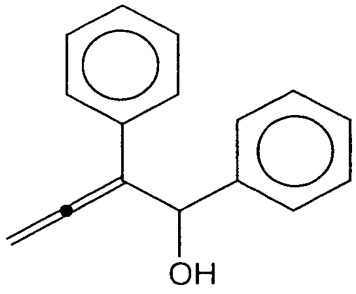
[0135]

^{1}H-NMR, δ: 0.04 (s, 9H), 2.90 (bs, 1H)
3.85 (s, 3H)
4.54 (dd, J=1.2 Hz, 2.1 Hz, 2H)
5.27 (bs, 1H)
7.38 (d, J=8.6 Hz, 2H)
7.94 (d, J=8.2 Hz, 2H)

^{13}C-NMR, δ: -1.08, 51.9, 72.2, 72.8, 100.8, 126.5, 129.1, 129.4, 148.4, 166.9, 207.8

IR: 700, 745, 830, 1005, 1035, 1100, 1185, 1275, 1405, 1435, 1605, 1700, 1920, 2945, 3440 (cm^{-1})

[0136]



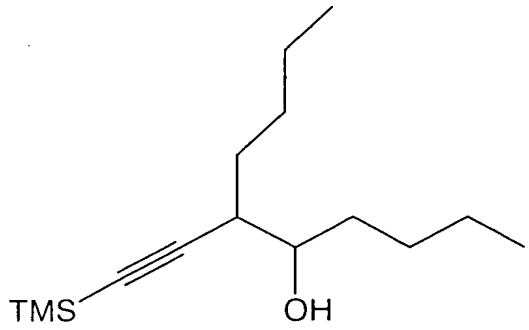
[0137]

^{1}H-NMR, δ: 5.17 (m, 2H)
5.65 (bs, 1H)
2.28 (bs, 1H)
7.1-7.5 (m, 10H)

^{13}C-NMR, δ: 72.3, 81.0, 109.8, 126.8, 126.9, 127.7, 128.3, 133.9, 141.9, 207.7

IR: 690, 760, 795, 850, 910, 950, 1020, 1180, 1255, 1380, 1450, 1490, 1595, 1705, 1880, 1935, 2910, 3030, 3390 (cm^{-1})

[0138]



(diastereo mixture)

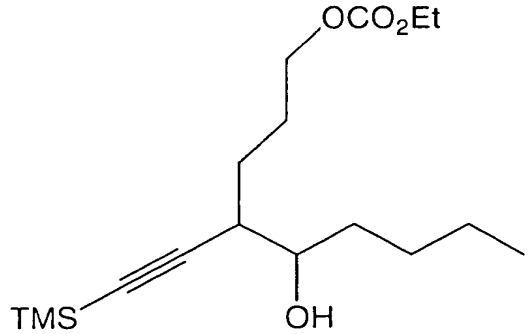
[0139]

^{1}H-NMR, δ: 0.135 (s, 9H) (minor)
0.142 (s, 9H) (major)
0.88 (t, J=6.5 Hz, 6H)
1.77 (bs, 1H) (minor)
1.80 (bs, 1H) (major)
2.41 (dt, J=4.5 Hz, 9.0 Hz, 1H) (major)
2.49 (dt, J=4.7 Hz, 9.3 Hz, 1H) (minor)
3.43 (m, 1H) (major)
3.53 (m, 1H) (minor)

^{13}C-NMR, δ: 0.13, 14.0, 22.5, 25.5, 27.1, 29.9, 31.5, 31.7, 33.7, 35.5, 40.2, 72.9 (major), 73.4 (minor), 87.7 (minor), 88.6 (major), 106.6 (major), 107.7 (minor)

IR: 690, 755, 840, 925, 1020, 1055, 1120, 1250, 1380, 1405, 1460, 2170, 2860, 2930, 3370 (cm^{-1})

[0140]



(diastereo mixture)

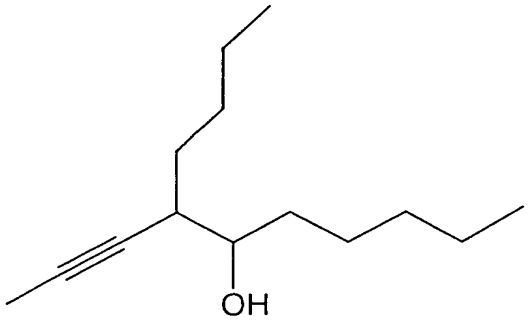
[0141]

^{1}H-NMR, δ: 0.13 (s, 9H) (minor)
0.14 (s, 9H) (major)
0.88 (t, J=6.7 Hz, 3H)
1.29 (t, J=7.1 Hz, 3H)
1.37-1.98 (m, 12H)
2.41-2.54 (m, 1H)
3.39-3.48 (1H) (major)
3.51-3.58 (1H) (minor)
4.15 (t, J=6.3 Hz, 2H)
4.17 (q, J=7.1 Hz, 2H)

^{13}C-NMR, δ: 0.06, 13.9, 14.2, 22.5, 25.3 (minor),
25.4 (major), 26.2 (minor),
26.7 (minor), 26.8 (major),
27.8, 31.7, 33.9 (minor), 35.4, 39.8, 63.8,
67.5 (major), 67.6 (minor),
72.9 (major), 73.3 (minor),
88.4 (minor), 89.3 (major),
105.5 (major), 106.8 (minor), 155.2

IR: 700, 770, 810, 855, 1025, 1095, 1270, 1385, 1465, 1605, 1755, 2170, 2950, 3450 (cm^{-1})

[0142]



(diastereo mixture)

[0143]

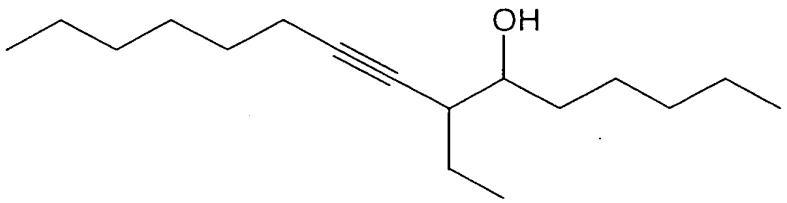
^{1}H-NMR, δ: 0.86 (t, J=6.5 Hz, 6H)
1.1-1.7 (m, 16H)
2.00 (bs, 1H)
2.07 (d, J=2.4 Hz) (minor)
2.10 (d, J=2.4 Hz) (major)
2.33-2.40 (m, 1H) (major)

2.45-2.49 (m, 1H) (minor)
3.37-3.57 (m, 1H)

^{13}C-NMR, δ: 13.9, 22.5, 25.4, 27.1,
30.0, 31.5, 31.7, 33.6,
35.4, 38.8 (major),
39.1 (minor), 71.1 (minor),
71.7 (major), 72.9 (major),
73.3 (minor), 84.1 (major),
85.0 (minor)

IR: 715, 845, 915, 1030, 1120, 1255, 1380, 1460, 1710,
2115, 2860, 2915, 3300, 3350 (cm^{-1})

[0144]



(diastereo mixture)

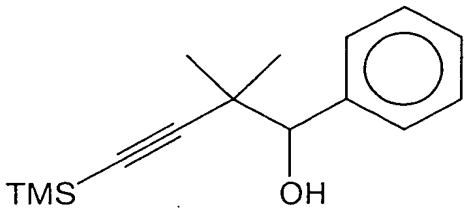
[0145]

^{1}H-NMR, δ: 0.86 (t, J=6.7 Hz, 6H)
0.98 (t, J=7.4 Hz, 3H)
1.2-1.6 (m, 18H)
1.82 (bs, 1H)
2.16 (dt, J=2.2 Hz, 6.9 Hz, 2H)
2.23-2.31 (m, 1H) (major)
2.32-2.42 (m, 1H) (minor)
3.35-3.45 (m, 1H) (major)
3.46-3.55 (m, 1H) (minor)

^{13}C-NMR, δ: 12.0, 12.1, 13.9, 18.7, 22.5, 22.6, 23.6, 25.3,
25.5, 28.5, 29.0, 31.3, 31.8, 33.8, 35.6, 41.1,
73.0 (major), 73.5 (minor),
79.0 (major), 80.2 (minor),
83.7 (minor), 84.6 (major)

IR: 720, 810, 905, 1015, 1085, 1155, 1250, 1375, 1455,
1735, 2120, 2860, 2920, 3365 (cm^{-1})

[0146]



[0147]

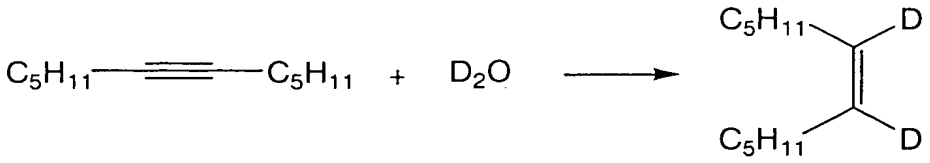
^{1}H-NMR, δ: 0.39 (s, 9H)
1.29 (s, 3H)
1.46 (s, 3H)
2.78 (d, J=4.4 Hz)
4.68 (d, J=4.1 Hz)
7.5-7.6 (m, 5H)

^{13}C-NMR, δ: 0.09, 24.6, 26.1, 80.1, 87.0, 111.6, 127.5, 127.7, 139.9

IR (NUJOR): 660, 710, 745, 765, 850, 915, 980, 1015, 1035, 1050, 1095, 1145, 1205, 1255, 1350, 1390, 1465, 1765, 2175, 2920, 3440 (cm^{-1})

Example 4-1

[0148]



[0149]

To 0.275 ml (0.938 mmol) of tetraisopropoxytitanium and 10 ml of ethyl ether solution containing 6-dodecyn (125 mg, 0.75 mmol) was added dropwise at -78°C under an argon atmosphere 1.53 ml of 1.53M ethyl ether solution containing isopropylmagnesium chloride (2.34 mmol). After heating to -50°C over 30 minutes, the reaction liquid was stirred for 2 hours. The reaction liquid was cooled to -78°C again and was given 1 ml of heavy water. The reaction liquid was heated to room temperature. With 1N hydrochloric acid added, the solution was separated into layers. The organic layer was dried with anhydrous magnesium sulfate and was freed of solvent by vacuum distillation. The residues were

purified by silica gel chromatography. Thus there was obtained 104 mg of (Z)-6,7-dideuterio-6-dodecene (yields: 81%).

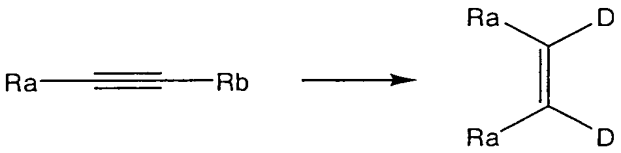
[0150]

Examples 4-2 to 4-6

The procedure of Example 4-1 was repeated except that the 6-dodecyn was replaced by those compounds shown in Table 6. There were obtained corresponding deuterio compounds in yields as shown in Table 6.

[0151]

Table 6



Example	Ra	Rb	Yields (%)	Z : E
4-1	C_5H_{11}	C_5H_{11}	81	>99:1
4-2	C_6H_{13}	Me	100	>99:1
4-3	C_6H_{13}	CH_2OEE	100	>99:1
4-4	Ph	Me	74	>99:1
4-5	Ph	Ph	96	99.4:0.6
4-6	Me_3Si	C_6H_{13}	94(89)	>99:1
4-7	Me_3Si	Me_3Si	100	>99:1

[0152]

Example 4-1: (Z)-6,7-Dideuterio-6-dodecene

^{1}H-NMR, δ: 0.89 (t, J=6.9 Hz, 6H)
1.21-1.42 (m, 12H)
2.01 (t, J=6.8 Hz, 4H)

^{13}C-NMR, δ: 14.04, 22.58, 27.05, 29.46, 31.55, 129.10, 129.40, 129.71

IR: 2925, 2855, 1730, 1460 (cm^{-1})

[0153]

Example 4-2: (Z)-2,3-Dideuterio-2-nonene

^{1}H-NMR, δ: 0.88 (t, J=6.0 Hz, 3H)
1.12-1.44 (m, 8H)
1.59 (s, 2H)
1.95-2.10 (m, 3H)

[0154]

Example 4-3: 1-Ethoxyethylether of (Z)-2,3-dideuterio-2-nonene-1-ol

^{1}H-NMR, δ: 0.88 (t, J=6.7 Hz, 3H)
1.22 (t, J=7.1 Hz, 3H)
1.33 (d, J=5.4 Hz, 3H)
1.18-1.42 (m, 8H)
2.06 (t, J=6.9 Hz, 2H)
3.50 and 3.64 (dq, J=9.4, 7.1 Hz, 2H)
4.10 (m, 2H)
4.74 (q, J=5.4 Hz, 1H)

^{13}C-NMR, δ: 13.93, 15.22, 19.74, 22.51, 27.32, 28.82, 29.43, 31.62, 60.24, 60.59, 98.85, 125.16, 125.49, 125.81, 132.49, 132.80, 133.10

IR: 2920, 2850, 2245, 1730, 1450, 1380, 1130, 1090, 1055, 930 (cm^{-1})

[0155]

Example 4-4: (Z)-1,2-Dideuterio-1-phenyl-1-propene

^{1}H-NMR, δ: 1.89 (s, 3H)
7.17-7.38 (m, 5H)

[0156]

Example 4-5: (Z)-1,2-Dideuterio-1,2-diphenylethylene

^{1}H-NMR, δ: 7.14-7.29 (m, 10H)

^{13}C-NMR, δ: 127.05, 128.16, 128.83, 129.40, 129.85, 137.13

IR: 3150, 1600, 1490, 1445, 750, 695 (cm^{-1})

[0157]

Example 4-6: (Z)-1,2-Dideuterio-1-(trimethylsilyl)-1-octene

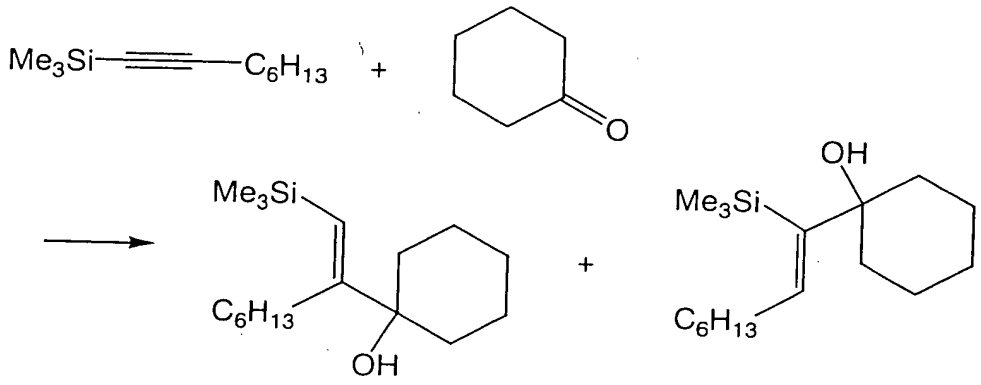
^{1}H-NMR, δ: 0.11 (s, 9H)
1.18-1.44 (m, 8H)
2.11 (t, J=7.0 Hz, 2H)

^{13}C-NMR, δ: 0.23, 14.06, 22.64, 29.06, 29.76, 31.82, 33.42, 127.87, 128.14, 128.41, 148.56, 148.87, 149.17

IR: 2925, 2855, 1585, 1460, 1250, 840, 755 (cm^{-1})

Example 5-1

[0158]



5-1A 5-1B

[0159]

To 0.22 ml (0.75 mmol) of tetraisopropoxytitanium and 8 ml of ethyl ether solution containing 1-trimethylsilyl-1-octyne (137 mg, 0.75 mmol) was added dropwise at -78°C under an argon atmosphere 1.20 ml of 1.25M ethyl ether solution containing isopropylmagnesium chloride (1.50 mmol). After heating to -50°C over 30 minutes, the reaction liquid was stirred for 2 hours. The reaction liquid was cooled to -78°C again and was given 0.054 ml (0.53 mmol) of cyclohexanone. The reaction liquid was stirred further at -75 to -70°C for 1 hour. The reaction liquid was given 0.8 ml of water and heated to room temperature. The reaction liquid was filtered through celite. The filtrate was dried with anhydrous magnesium sulfate and freed of solvent by vacuum distillation. The residues were purified by silica gel chromatography. Thus

there was obtained 124 mg of a mixture of 5-1A and 5-1B (yields: 84%, A:B = 96:4).

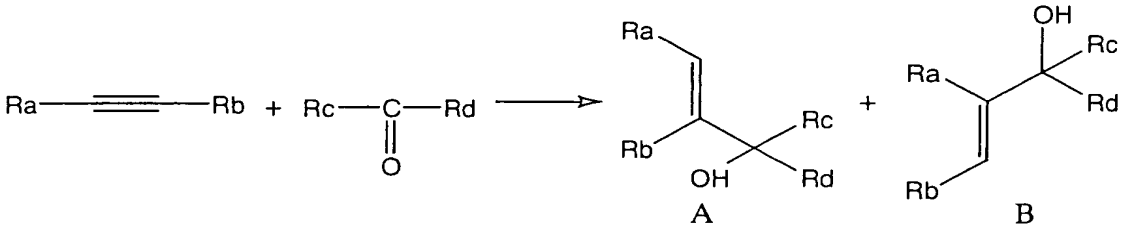
[0160]

Examples 5-2 to 5-10

The procedure of Example 5-1 was repeated except that the 1-trimethylsilyl-1-octyne and cyclohexanone were replaced by those compounds shown in Table 7. There were obtained corresponding alcohols in yields as shown in Table 7.

[0161]

Table 7



Example	Ra	Rb	RcCORd	Yields (%)	A : B
5-1	Me_3Si	C_6H_{13}	Cyclohexanone	84	96:4
5-2	C_5H_{11}	C_5H_{11}	Cyclohexanecarbaldehyde	70	-
5-3	Ph	Me	Cyclohexanecarbaldehyde	81	16:84
5-4	Me_3Si	C_6H_{13}	Hexanal	79	79:21
5-5	Me_3Si	C_6H_{13}	2-Methylbutanal	84	86:14
5-6	Me_3Si	C_6H_{13}	Cyclohexanecarbaldehyde	86	85:15
5-7	Me_3Si	C_6H_{13}	Crotonealdehyde	72	96:4
5-8	Me_3Si	C_6H_{13}	Benzaldehyde	47	93:7
5-9	Me_3Si	C_6H_{13}	Methyl-4-oxopentanoate	83	96:4
5-10	Me_3Si	Me_3Si	Cyclohexanecarbaldehyde	70	-

[0162]

Example 5-1: Reaction product of 5-1A + 5-1B (96:4)

^{1}H-NMR, δ: 0.11 (s, 9H(A))
0.22 (s, 9H(B))
0.89 (t, J=6.6 Hz, 3H)
1.12-1.72 (m, 19H)
2.10-2.19 (m, 2H)
5.55 (s, 1H(A))
6.14 (t, J=7.6 Hz, 1H(B))

^{13}C-NMR, δ: A: 0.94, 14.65, 22.70, 23.26, 26.12, 30.81, 32.36, 33.25, 33.38, 37.46, 76.15, 121.56, 166.48

IR: 3415, 2920, 2855, 1600, 1450, 1250, 840 (cm^{-1})

[0163]

Example 5-2: Reaction product of 5-2A

^{1}H-NMR, δ: 0.84-0.95 (m, 6H)
1.08-1.82 (m, 24H)
1.92-2.08 (m, 4H)
3.67 (d, J=7.7 Hz, 1H)
5.31 (t, J=7.4 Hz, 1H)

^{13}C-NMR, δ: 14.04, 22.49, 22.54, 26.06, 26.19, 26.51, 27.48, 27.78, 28.77, 29.50, 29.79, 30.03, 31.61, 32.48, 41.37, 82.09, 128.05, 140.82

IR: 3370, 2915, 2855, 1450, 995 (cm^{-1})

[0164]

Example 5-3: Reaction product of 5-3A + 5-3B (16:84)

^{1}H-NMR, δ: 0.89-1.93 (m, 12H)
1.55 (d, J=6.0 Hz, 3H(A))
1.85 (s, 3H(B))
3.83 (d, J=7.8 Hz, 1H(B))
4.00 (d, J=7.1 Hz, 1H(A))
5.74 (q, J=6.8 Hz, 1H(A))
6.42 (s, 1H(B))

^{13}C-NMR, δ: A: 14.23, 25.91, 26.04, 26.46, 27.85, 30.12, 40.88, 81.65, 123.88, 126.73, 128.05, 129.27, 138.40, 143.00
B: 126.36, 127.01, 128.95

IR: 3355, 2915, 2850, 1600, 1445, 1075, 1000, 700 (cm^{-1})

[0165]

Example 5-4: Reaction product of 5-4A + 5-4B (79:21)

^{1}H-NMR, δ: 0.11 (s, 9H(A))
0.17 (s, 9H(B))
0.82-0.97 (m, 6H)
1.17-1.69 (m, 13H)
1.96-2.08 (m, 1H(A))
2.08-2.26 (m, 1H(A) and 2H(B))
4.00-4.19 (m, 1H(A))
4.14 (dt, J=1.0, 5.0 Hz, 1H(B))
5.48 (s, 1H(A))
6.19 (dt, J=1.0, 5.0 Hz, 1H(B))

^{13}C-NMR, δ: A: 0.26, 14.01, 22.59, 25.44, 29.82, 29.87, 30.52, 31.72, 31.80, 33.54, 36.30, 37.83, 75.83, 121.79, 161.88
B: 0.77, 86.09, 142.07

IR: 3345, 2920, 2855, 1610, 1460, 1250, 835 (cm^{-1})

[0166]

Example 5-10: Reaction product of 5-10A

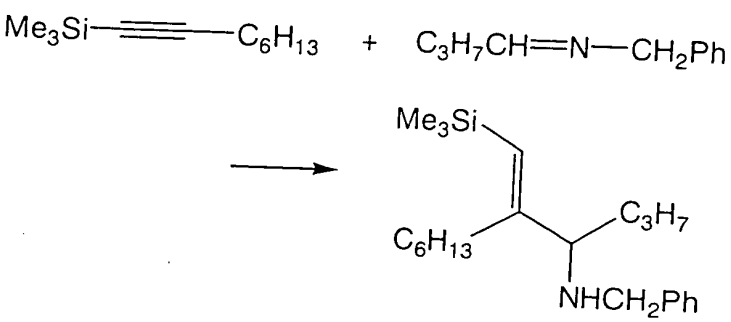
^{1}H-NMR, δ: 0.16 and 0.18 (s, 18H)
0.82-1.80 (m, 11H)
4.03 (d, J=4.9 Hz, 1H)
6.46 (s, 1H)

^{13}C-NMR, δ: 1.11, 26.16, 26.30, 26.54, 26.65, 30.94, 42.05, 82.93, 141.51, 162.53

IR: 3425, 2920, 2860, 1455, 1250, 1090, 1010, 835, 750 (cm^{-1})

Example 6-1

[0167]



[0168]

To 9 ml of ethyl ether solution of 0.33 g (1.16 mmol) of tetraisopropoxytitanium and 212 mg (1.16 mmol) of 1-trimethylsilyl-1-octyne was added dropwise at -78° C 1.16 ml of 2M ethyl ether solution containing isopropylmagnesium chloride (2.32 mmol). After heating to -50° C over 30 minutes, the reaction liquid was stirred for 2 hours. The reaction liquid was given 149 mg (0.93 mmol) of N-butylidenebenzylamine, stirred at -50° C for 1 hour, and heated to -10° C over 2 hours. The reaction liquid was given 2 ml of water and heated to room temperature. The reaction liquid was given 3 ml of 3N hydrochloric acid and stirred to dissolve precipitates completely. The solution was made alkaline with a saturated aqueous solution of sodium hydrogen carbonate. After extraction with 60 ml of hexane-ether mixture (1:1), the organic layer was dried with anhydrous magnesium sulfate and freed of solvent by vacuum distillation. The residues were purified by silica gel chromatography. Thus there was obtained 267 mg of 1-trimethyl-2-hexyl-3-(N-benzyl)amino-(E)-1-hexene (yields: 83%).

[0169]

Example 6-2

The procedure of Example 6-1 was repeated except that water was replaced by heavy water (D_2O). There was obtained a deuterio compound in a yield of 83% and a conversion of 94%.

[0170]

Example 6-3

The procedure of Example 6-1 was repeated except that water was replaced by iodine. There was obtained an iodinated compound in a yield of 76%.

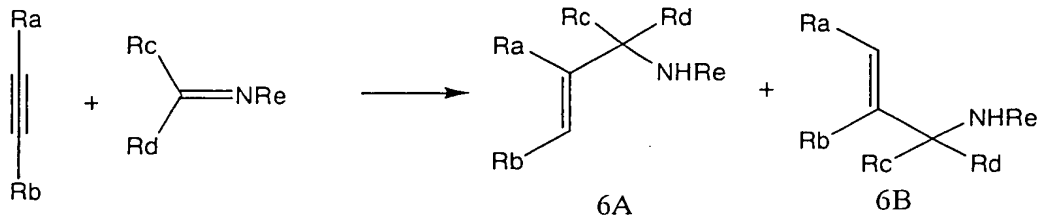
[0171]

Examples 6-4 to 6-16

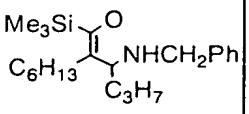
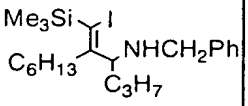
The procedure of Example 6-1 was repeated except that the 1-trimethylsilyl-1-octyne and N-butylidenebenzylamine were replaced by those compounds shown in Table 8. There were obtained corresponding amines in yields as shown in Table 8. Incidentally, the lithio salt of imine in Examples 6-14 to 6-16 was prepared by dropping a nitrile compound into a hexane-ether solution of methyl lithium at 0° C.

[0172]

Table 8



6A 6B

Example	Ra	Rb	Rc	Rd	Re	Post-treatment	Reaction product	Yields (%)
6-1	Me_3Si	C_6H_{13}	C_3H_7	H	CH_2Ph	H_2O	6B	83
6-2	Me_3Si	C_6H_{13}	C_3H_7	H	CH_2Ph	D_2O		83
6-3	Me_3Si	C_6H_{13}	C_3H_7	H	CH_2Ph	I_2		76
6-4	C_3H_7	C_3H_7	C_3H_7	H	CH_2Ph	H_2O	6B	75
6-5	Ph	CH_3	C_3H_7	H	CH_2Ph	H_2O	6A+6B(40:60)	71
6-6	Me_3Si	Ph	C_3H_7	H	CH_2Ph	H_2O	6B	72
6-7	Ph	Ph	C_3H_7	H	CH_2Ph	H_2O	6B	82
6-8	Me_3Si	C_6H_{13}	C_3H_7	H	C_3H_7	H_2O	6B	90
6-9	Me_3Si	C_6H_{13}	Ph	H	Ph	H_2O	6B	89
6-10	Me_3Si	C_6H_{13}	2-fulyl	H	CH_2Ph	H_2O	6B	82
6-11	Me_3Si	C_6H_{13}	Cyclohexyl	H	CH_2Ph	H_2O	6B	94
6-12	Me_3Si	C_6H_{13}	Ph	H	NMe_2	H_2O	6B	92
6-13	Me_3Si	C_6H_{13}	C_4H_9	CH_3	C_3H_7	H_2O	6B	54
6-14	Me_3Si	C_6H_{13}	C_2H_5	CH_3	Li	H_2O	6B	75
6-15	Me_3Si	C_6H_{13}	Ph	CH_3	Li	H_2O	6B	68
6-16	Me_3Si	C_6H_{13}	C_8H_{17}	CH_3	Li	H_2O	6B	60

[0173]

Reaction product in Example 6-1

^{1}H-NMR, δ: 7.18-7.40 (m, 5H)
5.43 (s, 1H)
3.72 (d, J=13.0 Hz, 1H)
3.47 (d, J=13.0 Hz, 1H)
3.01 (t, J=5.9 Hz, 1H)
2.08-2.21 (m, 1H)
1.93-2.08 (m, 1H)
1.20-1.50 (br m, 13H)
0.89 (t, J=6.6 Hz, 3H)
0.88 (t, J=7.1 Hz, 3H)
0.13 (s, 9H)

^{13}C-NMR, δ: 160.62, 141.18, 128.24, 128.14, 126.66, 122.93, 64.84, 51.42, 38.10, 34.10, 31.78, 30.64, 30.03, 22.63, 19.65, 14.19, 14.05, 0.44

IR: 2880, 1590, 1440, 1230, 1100, 920, 680 (cm^{-1})

[0174]

Reaction product in Example 6-4

^{1}H-NMR, δ: 7.18-7.37 (m, 5H)
5.28 (t, J=7.1 Hz, 1H)
3.72 (d, J=13.1 Hz, 1H)
3.52 (d, J=13.1 Hz, 1H)
2.97 (t, J=6.7 Hz, 1H)
1.86-2.12 (m, 4H)
1.20-1.52 (m, 9H)
0.94 (t, J=7.3 Hz, 3H)
0.93 (t, J=7.3 Hz, 3H)
0.87 (t, J=7.2 Hz, 3H)

^{13}C-NMR, δ: 141.30, 139.95, 128.23, 128.10, 127.96, 126.59, 65.04, 51.38, 37.35, 29.85, 29.74, 23.23, 23.16, 19.73, 14.85, 14.11, 13.90

IR: 3300 (br), 2920, 2860, 1600, 1455, 1120, 895, 730, 695 (cm^{-1})

[0175]

Reaction product in Example 6-5

^{1}H-NMR, δ: major isomer (A): 7.13-7.38 (m, 10H)
6.38 (s, 1H)
3.76 (d, J=13.2 Hz, 1H)
3.61 (d, J=13.2 Hz, 1H)
3.18 (t, J=7.0 Hz, 1H)
1.83 (s, 3H),
1.39-1.65 (m, 3H)
1.21-1.39 (m, 2H)
0.90 (t, J=7.3 Hz, 3H)
minor isomer (B):7.10-7.41 (m, 10H)
5.65 (q, J=5.7 Hz, 1H)
3.95 (d, J=13.4 Hz, 1H)
3.72 (d, J=13.4 Hz, 1H)
3.24 (t, J=5.9 Hz, 1H)
1.55 (d, J=6.8 Hz, 3H)
1.20-1.45 (m, 5H)
0.84 (t, J=6.8 Hz, 3H)

^{13}C-NMR, δ: major isomer (A): 140.91, 139.35,
138.05, 128.93, 128.28, 128.17,
128.04, 127.54, 126.73, 126.12, 66.27, 51.35,
36.48, 19.67, 14.13, 12.44
minor isomer (B):
142.31, 141.01, 138.96, 129.20, 128.28, 128.11,
127.93, 126.69, 126.51, 124.07, 64.90, 51.23,
36.90, 19.59, 14.34, 14.04

IR: major isomer (A): 3300 (br), 2900, 1590, 1440, 1105,
830, 715, 685
minor isomer (B): 3300 (br), 3010, 2920, 2850, 1590,
1490, 1450, 1360, 1110, 1070, 900,
830, 730, 690 (cm^{-1})

[0176]

Reaction product in Example 6-6

^{1}H-NMR, δ: 7.47-7.68 (m, 8H)
7.33-7.42 (m, 2H)
5.99 (s, 1H)
4.22 (d, J=13.2 Hz, 1H)
3.98 (d, J=13.2 Hz, 1H)
3.54 (t, J=5.3 Hz, 1H)
1.48-1.77 (m, 5H)
1.12 (t, J=6.2 Hz, 3H)
0.10 (s, 9H)

^{13}C-NMR, δ: 159.01, 141.86, 140.94, 128.84, 128.75, 128.30, 128.17, 127.58, 126.91, 126.75, 67.11, 51.37, 36.78, 19.45, 14.06, 0.03

IR: 3350 (br), 3025, 2920, 1590, 1450, 1245, 1120, 850, 830, 740, 690 (cm^{-1})

[0177]

Reaction product in Example 6-7

^{1}H-NMR, δ: 6.87-7.41 (m, 15H)
6.54 (s, 1H)
4.03 (d, J=13.4 Hz, 1H)
3.80 (d, J=13.4 Hz, 1H)
3.40 (t, J=5.2 Hz, 1H)
1.22-1.58 (m, 5H)
0.87 (t, J=5.5 Hz, 3H)

^{13}C-NMR, δ: 143.36, 140.89, 139.20, 136.92, 129.14 (2 peaks), 128.56, 128.50, 128.33, 128.13, 127.85, 127.04, 126.78, 126.42, 65.85, 51.35, 36.84, 19.60, 14.06

IR: 3400 (br), 3020, 2925, 1595, 1490, 1445, 1120, 1070, 1020, 905, 730, 690 (cm^{-1})

[0178]

Reaction product in Example 6-8

^{1}H-NMR, δ: 5.32 (s, 1H)
2.94 (t, J=6.2 Hz, 1H)
2.38-2.50 (m, 1H)

2.26-2.38 (m, 1H)
2.03-2.16 (m, 1H)
1.88-2.01 (m, 1H)
1.11-1.52 (m, 15H)
0.88 (t, J=7.3 Hz, 6H)
0.87 (t, J=7.0 Hz, 3H)
0.09 (s, 9H)

^{13}C-NMR, δ: 160.92, 122.59, 65.39, 49.40, 38.07, 34.19, 31.80, 30.58, 30.03, 23.38, 22.64, 19.62, 14.22, 14.04, 11.86, 0.39

IR: 3350 (br), 2925, 2850, 1610, 1460, 1245, 1140, 840, 680

[0179]

Reaction product in Example 6-9

^{1}H-NMR, δ: 7.21-7.37 (m, 5H)
7.13 (dd, like t, J=J=7.9 Hz, 2H)
6.68 (dd, like t, J=J=7.3 Hz, 1H)
6.54 (d, J=8.4 Hz, 2H)
5.68 (s, 1H)
4.81 (s, 1H)
3.95 (br s, 1H)
2.18-2.32 (m, 1H)
1.90-2.03 (m, 1H)
1.37-1.61 (m, 2H)
1.20-1.37 (br s, 6H)
0.88 (t, J=6.6 Hz, 3H)
0.10 (s, 9H)

^{13}C-NMR, δ: 157.43, 147.63, 142.01, 128.95, 128.58, 127.71, 127.36, 124.30, 117.25, 113.33, 64.49, 34.74, 34.68, 31.67, 29.96, 22.60, 14.02, 0.29

IR: 3380, 2900, 2840, 1595, 1500, 1305, 1240, 830, 740, 680 (cm^{-1})

[0180]

Reaction product in Example 6-10

^{1}H-NMR, δ: 7.37 (m, 1H)
7.18-7.35 (m, 5H)
6.30 (dd, J=3.1, J=1.8 Hz, 1H)
6.12 (d, J=3.1 Hz, 1H)
5.81 (s, 1H)
4.13 (s, 1H)
2.65 (s, 2H)
2.00-2.14 (m, 1H)
1.69-1.87 (m, 1H)
1.75 (br s, 1H)
1.12-1.38 (br s, 8H)
0.86 (t, J=6.8 Hz, 3H)
0.13 (s, 9H)

^{13}C-NMR, δ: 158.95, 154.17, 142.39, 141.64, 128.27, 127.99, 127.15, 122.34, 110.02, 106.90, 67.06, 44.01, 34.42, 31.66, 29.99, 29.65, 22.55, 14.02, 0.39

IR: 2925, 1600, 1455, 1250, 1150, 1010, 840, 735, 700 (cm^{-1})

[0181]

Reaction product in Example 6-11

^{1}H-NMR, δ: 7.17-7.39 (m, 5H)
5.33 (s, 1H)
3.73 (d, J=13.2 Hz, 1H)
3.45 (d, J=13.2 Hz, 1H)
2.75 (d, J=6.8 Hz, 1H)
2.07-2.21 (m, 1H)
1.80-2.01 (m, 2H)
0.97-1.80 (m, 19H)
0.89 (t, J=6.3 Hz, 3H)
0.12 (s, 9H)

^{13}C-NMR, δ: 159.07, 141.39, 128.18, 128.14, 126.60, 124.04, 70.59, 51.61, 41.69, 34.63, 31.81, 31.07, 30.69, 30.11, 29.25, 26.71, 26.63, 26.57, 22.65, 14.06, 0.49

IR: 3350 (br), 2910, 2850, 1605, 1450, 1250, 1010, 840, 730, 690 (cm^{-1})

[0182]

Reaction product in Example 6-12

^{1}H-NMR, δ: 7.18-7.36 (m, 5H)
5.76 (s, 1H)
4.38 (s, 1H)
2.97 (s, 1H)
2.44 (s, 6H)
1.97-2.17 (m, 1H)
1.82-1.97 (m, 1H)
1.21 (br s, 8H)
0.86 (t, J=6.7 Hz, 3H)
0.11 (s, 9H)

^{13}C-NMR, δ: 158.96, 141.25, 128.17, 127.86, 126.99, 125.57, 123.39, 67.86, 48.05, 34.73, 31.65, 30.09, 29.13, 22.56, 14.01, 0.38

IR: 3350 (br), 2925, 2850, 1600, 1460, 1250, 1020, 840, 745, 695 (cm^{-1})

[0183]

Reaction product in Example 6-13

^{1}H-NMR, δ: 5.32 (s, 1H)
2.27-2.39 (m, 1H)
2.16-2.27 (m, 1H)
1.99-2.09 (m, 2H)
1.35-1.52 (m, 7H)
0.99-1.35 (m, 10H)
1.15 (s, 3H)
0.89 (t, J=7.4 Hz, 6H)
0.87 (t, J=7.3 Hz, 3H)
0.10 (s, 9H)

^{13}C-NMR, δ: 162.11, 123.97, 61.38, 44.42, 40.23, 32.58, 32.27, 31.79, 30.30, 26.26, 23.93, 23.73, 23.20, 22.64, 14.06, 14.02, 11.99, 0.45

IR: 3350 (br), 2920, 1595, 1460, 1370, 1245, 840, 680 (cm^{-1})

[0184]

Reaction product in Example 6-14

^{1}H-NMR, δ: 5.42 (s, 1H)
1.98-2.17 (m, 2H)
1.19-1.62 (m, 12H)
1.18 (s, 3H)
0.87 (t, J=6.7 Hz, 3H)
0.73 (t, J=7.4 Hz, 3H)
0.09 (s, 9H)

^{13}C-NMR, δ: 164.84, 121.74, 58.15, 34.63, 33.01, 32.67, 31.75, 30.26, 28.82, 22.65, 14.02, 8.54, 0.39

IR: 3300 (br), 2920, 1595, 1455, 1370, 1240, 835, 680 (cm^{-1})

[0185]

Reaction product in Example 6-15

^{1}H-NMR, δ: 7.16-7.42 (m, 5H)
5.76 (s, 1H)
1.86-1.97 (m, 2H)
1.77 (br s, 2H)
1.58 (s, 3H)
1.06-1.25 (m, 8H)
0.82 (t, J=6.9 Hz, 3H)
0.17 (s, 9H)

^{13}C-NMR, δ: 164.48, 147.99, 128.01, 126.23, 125.73, 121.50, 61.41, 33.57, 32.53, 31.54, 30.05, 29.75, 2.50, 13.97, 0.32

IR: 3300 (br), 2920, 1600, 1440, 1245, 840, 760, 695 (cm^{-1})

[0186]

Reaction product in Example 6-16

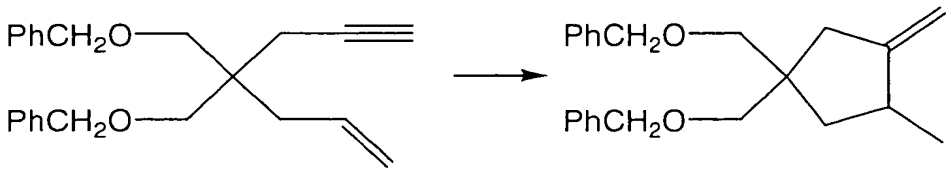
^{1}H-NMR, δ: 5.43 (s, 1H)
2.00-2.19 (m, 2H)
1.35-1.62 (m, 6H)
1.02-1.35 (m, 18H)
1.19 (s, 3H)
0.89 (t, J=6.5 Hz, 3H)
0.87 (t, J=6.9 Hz, 3H)
0.11 (s, 9H)

^{13}C-NMR, δ: 165.36, 121.39, 58.02, 42.35, 33.07, 32.69, 31.86, 31.77, 30.27, 30.06, 29.54, 29.32, 29.25, 24.23, 22.66 (2 peaks), 14.07, 14.04, 0.41

IR: 2910, 2850, 1590, 1455, 1370, 1245, 830 (cm^{-1})

Example 7-1

[0187]



7-1S 7-1P

[0188]

To 9.5 ml of ethyl ether were added under an argon atmosphere 0.37 ml (1.26 mmol) of tetraisopropoxytitanium and 330 mg (1.0 mmol) of the unsaturated compound 7-1S. After cooling to -78°C, the reaction liquid was given dropwise 2.55 ml (2.77 mmol) of isopropylmagnesium chloride. The reaction liquid was stirred at -78°C for 30 minutes, heated to -50°C over 30 minutes, and stirred for 2 hours. After cooling again to -78°C, the reaction liquid was given 2 ml of 3N hydrochloric acid. The reaction liquid was heated to room temperature and extracted with hexane-ether mixture. The organic layer was washed with a saturated aqueous solution of sodium hydrogen carbonate and a saturated aqueous solution of sodium chloride. The solution was dried with anhydrous magnesium sulfate and freed of solvent by vacuum distillation. The residues were purified by silica gel chromatography. Thus there was obtained 263 mg of 7-1P in the cyclized form (yields: 79%).

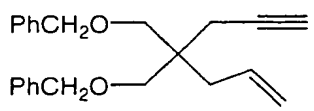
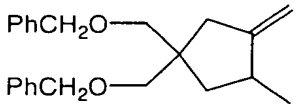
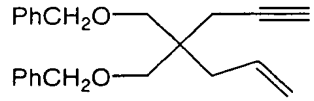
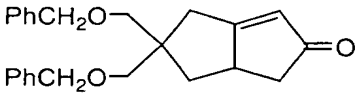
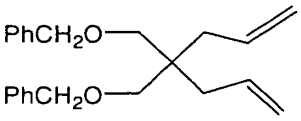
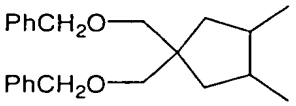
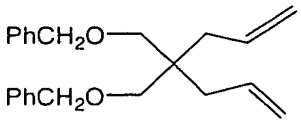
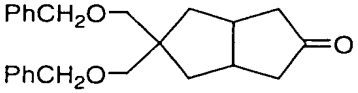
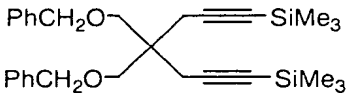
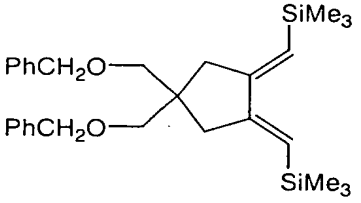
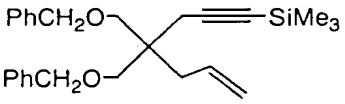
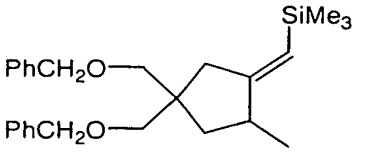
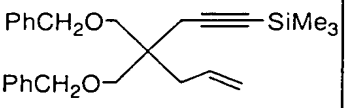
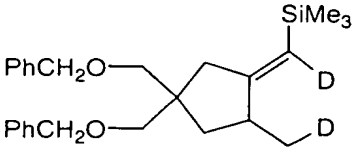
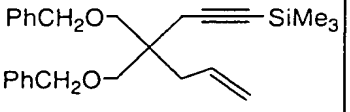
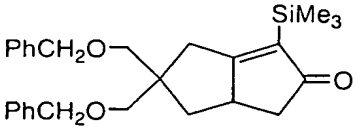
[0189]

Examples 7-2 to 7-13

The procedure of Example 7-1 was repeated except that the unsaturated compound and terminator were replaced by those shown in Tables 9 and 10. There were obtained corresponding cyclized compounds in yields as shown in Tables 9 and 10.

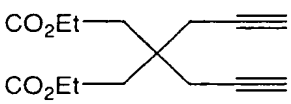
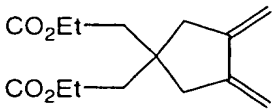
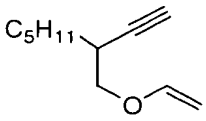
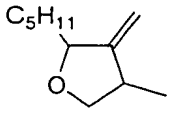
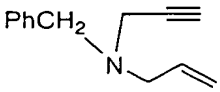
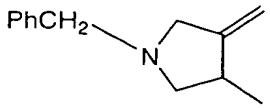
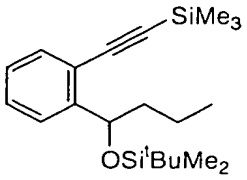
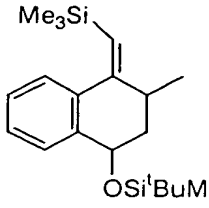
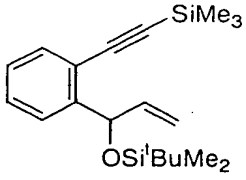
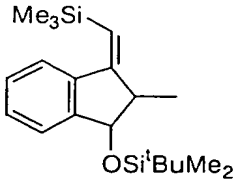
[0190]

Table 9

Example	Starting material	Terminator	Reaction product	Yields (%)
7-1		H_2O		79
7-2		CO		14
7-3		H_2O		77
7-4		CO		51
7-5		H_2O		97
7-6		H_2O		97
7-7		D_2O		90
7-8		CO		56

[0191]

Table 10

Example	Starting material	Terminator	Reaction product	Yields (%)
7-9		H_2O		22
7-10		H_2O		65
7-11		H_2O		53
7-12		H_2O		47
7-13		H_2O		46

[0192]

Reaction product in Example 7-2

^{1}H-NMR, δ: 1.11 (t, J=12.3 Hz, 1H)
2.03 (dd, J=2.9, 14.9 Hz, 1H)
2.17 (dd, J=8.5, 4.1 Hz, 1H)
2.54-2.64 (m, 1H)
3.05-3.20 (m, 1H)
3.22-3.63 (m, 4H)
4.35-4.60 (m, 4H)
5.82-5.86 (m, 1H)
7.17-7.49 (m, 10H)

IR: 3030, 2850, 1700 (C=0), 1630, 1455, 1410, 1360, 1260, 1205, 1090, 905, 830, 740, 700 (cm^{-1})

[0193]

Reaction product in Example 7-3

^{1}H-NMR, δ: 0.83 and 0.90 (2d, J=6.8 Hz and 6.0 Hz, 6H)
1.03 and 1.24 (2dd, J=13.1 Hz and13.6 Hz, 2H)
1.67 and 1.79 (2dd, J=6.6, 5.3, 6.6 Hz and 7.4, 6.1, 7.5 Hz, 2H)
1.18-1.43 and 1.96-2.08 (m, 2H)
3.34 and 3.40 (s, 4H)
4.51 (s, 4H)
7.22-7.40 (m, 10H)

IR: 3025, 2850, 1600, 1450, 1355, 1245, 1200, 1090, 900, 835, 730, 690 (cm^{-1})

[0194]

Reaction product in Example 7-4

^{1}H-NMR, δ: 1.45 (dd, J=6.8, 7.2 Hz, 2H)
1.94 (dd, J=8.2, 5.6 Hz, 2H)
2.11 (dd, J=4.8, 14.7 Hz, 2H)
2.41 (dd, J=9.1, 8.4 Hz, 2H)
2.57-2.81 (m, 2H)
3.34 (s, 2H)
3.40 (s, 2H)
4.35-4.55 (m, 4H)
7.15-7.38 (m, 10H)

IR: 2850, 1735, 1455, 1410, 1360, 1200, 1100, 1030, 910, 740, 695 (cm^{-1})

[0195]

Reaction product in Example 7-5

^{1}H-NMR, δ: 0.17 (s, 18H)
2.47 (d, J=2.1 Hz)
3.42 (s, 4H)
4.55 (s, 4H)
6.00-6.09 (m, 2H)
7.25-7.45 (m, 10H)

^{13}C-NMR, δ: -0.46, 38.60, 45.15, 72.95, 73.27, 118.29, 127.34, 127.40, 128.25, 138.81, 156.30

IR: 3030, 2950, 2850, 1600, 1450, 1360, 1245, 1100, 840, 730, 690 (cm^{-1})

[0196]

Reaction product in Example 7-6

^{1}H-NMR, δ: 0.09 (s, 9H)
1.03 (d, J=6.7 Hz, 3H)
1.07 (dd, J=12.8 Hz, 2.0 Hz, 1H)
1.94 (dd, J=12.9 Hz, 4.7 Hz, 1H)
2.30-2.36 (m, 2H)
2.40-2.57 (m, 2H)
3.30-3.42 (m, 4H)
4.45-4.53 (m, 4H)
5.18-5.28 (m, 1H)
7.20-7.37 (m, 10H)

^{13}C-NMR, δ: -0.19, 18.74, 39.24, 39.88, 45.80, 73.07, 73.78, 74.88, 117.19, 127.29, 127.32, 127.39, 128.23, 138.91, 165.85

IR: 3025, 2850, 1620, 1450, 1355, 1240, 1200, 1090, 835, 730, 690 (cm^{-1})

[0197]

Reaction product in Example 7-7

^{1}H-NMR, δ: 0.08 (s, 9H)
1.07 (dd, J=10.9, 2.0 Hz, 1H)
1.94 (dd, J=8.3, 4.6 Hz, 1H)
2.40-2.55 (m, 1H)
3.27-3.43 (m, 4H)
4.51 (s, 4H)
7.22-7.42 (m, 10H)

[0198]

Reaction product in Example 7-10

^{1}H-NMR, δ: 0.82-0.96 (m, 3H)
1.06-1.14 (m, 3H)
1.20-1.70 (m, 8H)
2.60-2.82 (m, 1H)

3.24 and 3.44 and 3.93 and 4.11
(4dd, J=8.3, 6.5, 7.4, 7.7 Hz, 2H)
4.24-4.37 (m, 1H)
4.80-4.92 (m, 2H)

^{13}C-NMR, δ: 14.01, 15.05, 17.38, 22.61, 25.04, 25.57, 31.90, 35.13, 35.76, 38.47, 38.75, 73.15, 74.12, 81.14, 81.45, 102.75, 103.07, 157.13, 157.23

IR: 2920, 2850, 1660, 1450, 1375, 1260, 1080, 1030, 880, 800 (cm^{-1})

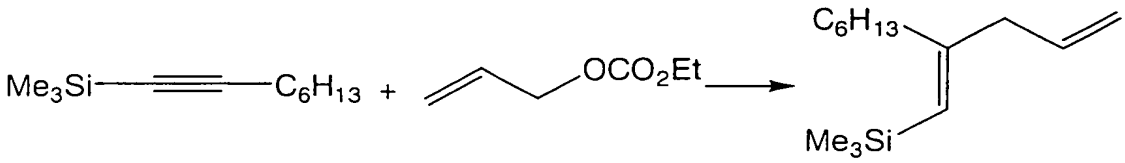
[0199]

Reaction product in Example 7-12

^{1}H-NMR, δ: 0.00 and 0.03 (2s, 9H)
0.08 and 0.12 (2s, 6H)
0.80-1.00 (m, 9H)
1.08 and 1.14 (2d, J=6.9, 6.9 Hz, 3H)
1.62-1.73 and 1.97-2.09 and 2.18-2.40 and 2.65-2.85 (4m, 3H)
4.60 and 4.76 (q and t, J=5.2, 5.6, 5.2 Hz and J=5.8 Hz, 1H)
5.43-5.47 (m, 1H)
7.15-7.52 (m, 6H)

Example 8-1

[0200]



[0201]

To 9 ml of ethyl ether solution containing 170 mg (0.934 mmol) of 1-trimethylsilyl-1-octyne, 121 mg (0.934 mmol) of allyl carbonate, and 0.342 ml (1.17 mmol) of tetraisopropoxytitanium was added dropwise at -78°C 1.72 ml of 1.49M ethyl ether solution containing isopropylmagnesium bromide (2.57 mmol). After heating to -50°C over 30 minutes, the reaction liquid was stirred for 2 hours. The reaction liquid was cooled to -78°C again and given 2 ml of

water. The reaction liquid was stirred together with 10 ml of 1N hydrochloric acid for 30 minutes. After extraction with hexane, the organic layer was dried with anhydrous magnesium sulfate and freed of solvent by vacuum distillation. The residues were purified by silica gel chromatography. Thus there was obtained 1-trimethyl-2-hexyl-1,4-pentadiens in a yield of 83%.

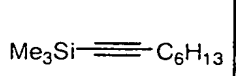
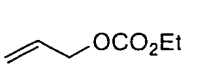
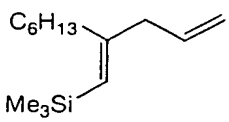
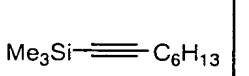
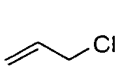
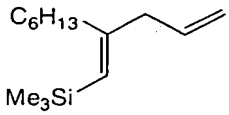
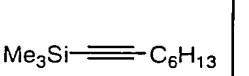
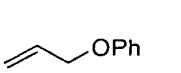
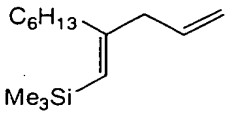
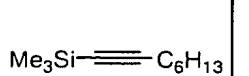
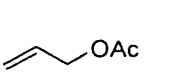
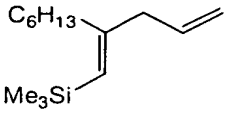
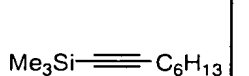
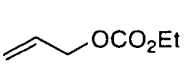
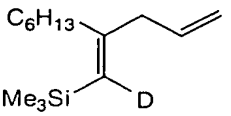
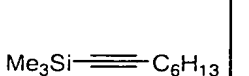
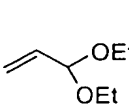
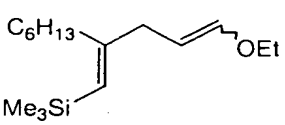
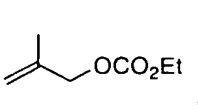
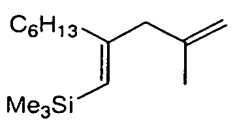
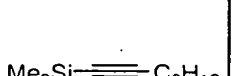
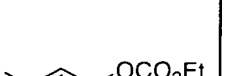
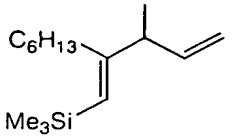
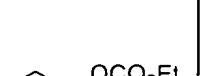
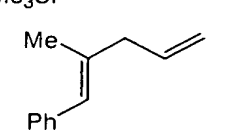
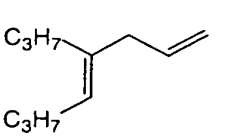
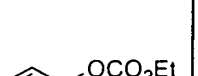
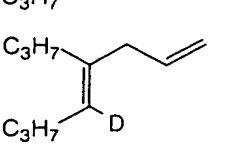
[0202]

Examples 8-2 to 8-11

The procedure of Example 8-1 was repeated except that the 1-trimethylsilyl-1-octyne and allyl carbonate were replaced those shown in Tables 11 and 12. There were obtained corresponding dienes in respective yields as shown in Tables 11 and 12.

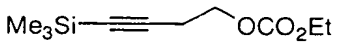
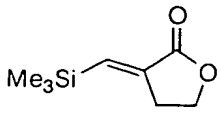
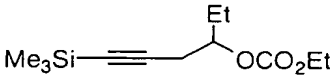
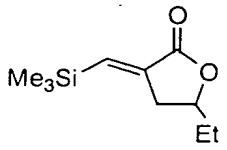
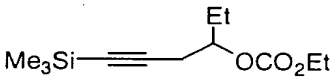
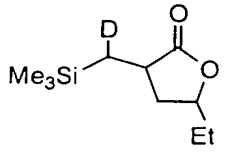
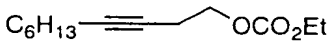
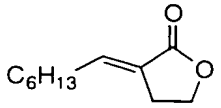
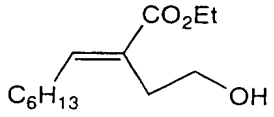
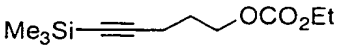
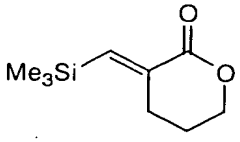
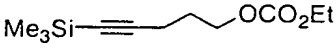
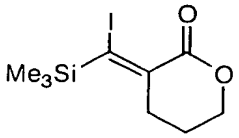
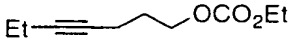
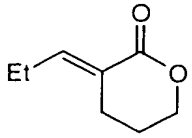
[0203]

Table 11

Example	Acetylene compound	Allyl compound	Reaction product	Yields (%)
8-1				83
8-2				72
8-3				80
8-4				55
8-5		 (D_2O termination)		77
8-6				64 (E:Z=95:5)
8-7				20
8-8				16
8-9				65
8-10				66
8-11		 (D_2O termination)		70

[0204]

Table 12

Example	Acetylene compound	Terminator	Reaction product	Yields (%)
9-1		H_2O		81
9-2		H_2O		84
9-3		D_2O		88
9-4		H_2O		62
				20
9-5		H_2O		76
9-6		I_2		74
9-7		H_2O		65

[0205]

Reaction product in Example 8-1

^{1}H-NMR, δ: 0.097 (s, 9H)
0.89 (t, J=6.7 Hz, 3H)
1.23-1.47 (m, 8H)
2.12 (t, J=7.9 Hz, 2H)
2.82 (d, J=7.0 Hz, 2H)
4.99-5.03 (m, 1H)
5.06 (s, 1H)
5.20 (s, 1H)
5.73-5.88 (m, 1H)

^{13}C-NMR, δ: 0.37, 14.05, 22.62, 29.03, 29.59, 31.82, 36.24, 115.90, 124.30, 136.88, 157.96

IR: 2930, 1610, 1250, 840 (cm^{-1})

Elemental analysis value $C_{14}H_{28}Si$:
Calculated value C74.92; H12.57
Found value C74.90; H12.49

[0206]

Reaction product in Example 8-6
(E isomer)

^{1}H-NMR, δ: 0.085 (s, 9H)
0.89 (t, J=6.7 Hz, 3H)
1.18-1.44 (m, 11H)
2.11 (t, J=7.8 Hz, 2H)
2.66 (d, J=7.4 Hz, 2H)
3.74 (q, J=14.0 Hz, 2H)
4.70-4.80 (m, 1H)
5.22 (s, 1H)
6.20 (d, J=12.5 Hz, 1H)

^{13}C-NMR, δ: 0.396, 14.03, 14.77, 22.61, 29.10, 29.61, 31.82, 36.04, 37.20, 64.69, 102.14, 123.20, 147.08, 159.41

IR: 2918, 1645, 1607, 1245, 1200, 1153, 832 (cm^{-1})

(Z isomer)

^{1}H-NMR, δ: 0.085 (s, 9H)
0.89 (t, J=6.7 Hz, 3H)
1.18-1.44 (m, 11H)
2.11 (t, J=7.8 Hz, 2H)
2.86 (d, J=7.4 Hz, 2H)
3.78 (q, J=12.8 Hz, 2H)
4.37 (q, J=13.8 Hz, 1H)
5.21 (s, 1H)
6.01 (d, J=6.2 Hz, 1H)

^{13}C-NMR, δ: 0.396, 14.03, 15.26, 22.61, 29.10, 29.61, 33.57, 36.32, 37.20, 67.49, 104.88, 122.62, 145.23, 159.08

[0207]

Reaction product in Example 8-7

^{1}H-NMR, δ: 0.097 (s, 9H)
0.89 (t, J=6.6 Hz, 3H)
1.23-1.42 (m, 8H)
1.65 (s, 3H)
2.07 (t, J=7.9 Hz, 2H)
2.78 (s, 2H)
4.7130 (s, 1H)
4.7963 (s, 1H)
5.22 (s, 1H)

^{13}C-NMR, δ: 0.34, 14.05, 21.84, 22.63, 29.12, 29.71, 31.82, 35.45, 48.43, 112.16, 125.57, 144.06, 157.16

[0208]

Reaction product in Example 8-8

^{1}H-NMR, δ: 0.11 (s, 9H)
0.88 (t, J=6.2 Hz, 3H)
1.10 (d, J=6.9 Hz, 3H)
1.22-1.45 (m, 8H)
2.07-2.14 (m, 2H)
2.78-2.88 (m, 1H)
4.91-5.01 (m, 2H)

5.20 (s, 1H)
5.68-5.80 (m, 1H)

[0209]

Reaction product in Example 8-9

^{1}H-NMR, δ: 1.86 (s, 3H)
2.91 (d, J=6.8 Hz, 2H)
5.07-5.16 (m, 2H)
5.82-5.96 (m, 1H)
6.30 (s, 1H)
7.16-7.34 (m, 5H)

^{13}C-NMR, δ: 17.80, 44.95, 116.28, 125.75, 125.94, 127.99, 128.78, 136.38, 137.28, 138.43

IR: 2907, 1639, 1602, 997, 918, 740, 700 (cm^{-1})

[0210]

Reaction product in Example 8-10

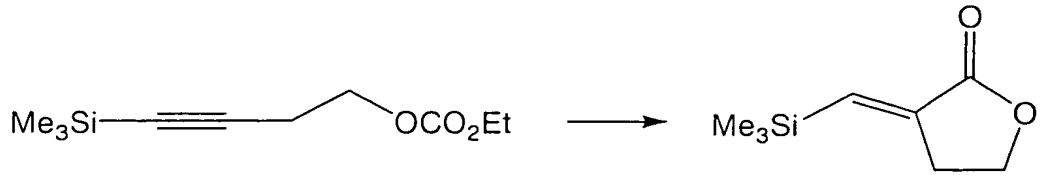
^{1}H-NMR, δ: 0.87-0.93 (m, 6H)
1.30-1.42 (m, 4H)
1.95-2.02 (m, 4H)
2.72 (d, J=6.7 Hz, 2H)
4.98-5.05 (m, 2H)
5.17 (t, J=7.3 Hz, 1H)
5.72-5.86 (m, 1H)

^{13}C-NMR, δ: 13.87, 14.10, 21.43, 23.17, 29.94, 32.18, 41.53, 115.29, 126.19, 137.58, 137.64

IR: 2922, 2870, 1636, 1458, 995, 910 (cm^{-1})

Example 9-1

[0211]



[0212]

To 7.5 ml of ethyl ether solution containing 284 ml (1.0 mmol) of tetraisopropoxytitanium and 0.5 mmol of 1-trimethylsilyl-1-butyne-4-carbonate was added dropwise at -50°C 1.54 ml of 1.3M ethyl ether solution containing

isopropylmagnesium bromide (2 mmol). The reaction liquid was stirred at -45 to -40°C for 1 hour. The reaction liquid was given 5 ml of 1N hydrochloric acid at -40°C and then heated to room temperature and stirred for 30 minutes. After layer separation, the organic layer was washed with a saturated aqueous solution of sodium hydrogen carbonate, dried with anhydrous magnesium sulfate, and freed of solvent by vacuum distillation. The residues were purified by silica gel chromatography. Thus there was obtained lactone in a yield of 81%.

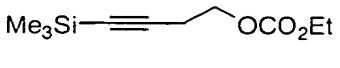
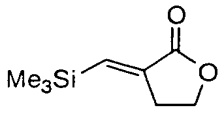
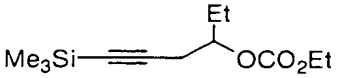
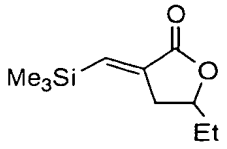
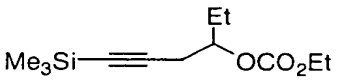
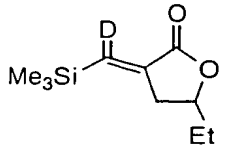
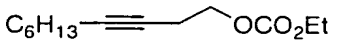
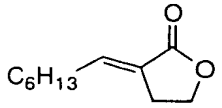
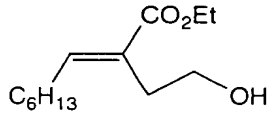
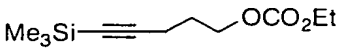
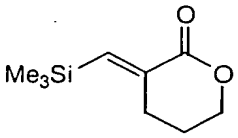
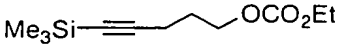
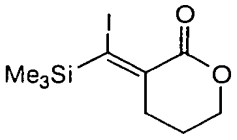
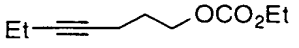
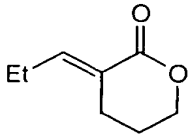
[0213]

Examples 9-2 to 9-10

The procedure of Example 9-1 was repeated except that the 1-trimethylsilyl-1-butyne-4-carbonate and terminator (1N hydrochloric acid) were replaced by those shown in Tables 13 and 14. There were obtained corresponding lactones or α,β-unsaturated esters in respective yields as shown in Tables 13 and 14.

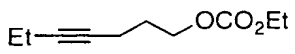
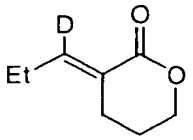
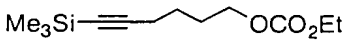
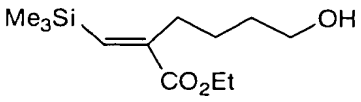
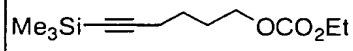
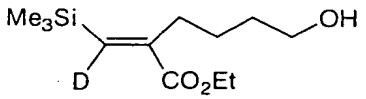
[0214]

Table 13

Example	Acetylene compound	Terminator	Reaction product	Yields (%)
9-1		H_2O		81
9-2		H_2O		84
9-3		D_2O		88
9-4		H_2O		62
				20
9-5		H_2O		76
9-6		I_2		74
9-7		H_2O		65

[0215]

Table 14

Example	Acetylene compound	Terminator	Reaction product	Yields (%)
9-8		D_2O		63
9-9		H_2O		66
9-10		D_2O		64

[0216]

Reaction product in Example 9-1

^{1}H-NMR, δ: 0.22 (s, 9H)
2.98 (d/t, J=2.1, 6.6 Hz, 2H)
4.40 (t, J=6.6 Hz, 2H)
6.97 (t, J=2.1 Hz, 1H)

^{13}C-NMR, δ: -1.49, 27.23, 64.92, 138.79, 139.46, 170.39

[0217]

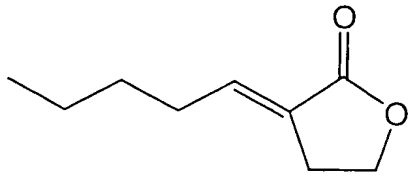
Reaction product in Example 9-2

^{1}H-NMR, δ: 0.17 (s, 9H)
0.98 (t, J=6.9 Hz, 3H)
1.67 (m, 2H)
2.50 (d/d/d, J=17.4, 6.0, 2.4 Hz, 1H)
3.01 (d/d/d, J=17.4, 6.6, 2.4 Hz, 1H)
4.43 (t/t, J=6.3, 6.3 Hz, 1H)
6.88 (t, J=2.4 Hz, 1H)

^{13}C-NMR, δ: -1.49, 8.89, 29.18, 33.02, 78.18, 138.94, 140.16, 170.00

Reaction product in Example 9-4

[0218]

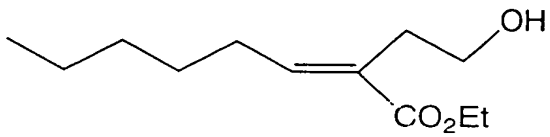


[0219]

^{1}H-NMR, δ: 0.89 (t, J=6.8 Hz, 3H)
1.30 (m, 6H)
1.49 (m, 2H)
2.20 (d/t, J=7.2, 7.2 Hz, 2H)
2.87 (m, 2H)
4.37 (t, J=7.8 Hz, 2H)
6.74 (m, 1H)

^{13}C-NMR, δ: 13.93, 22.44, 25.02, 28.03, 28.89, 30.16, 31.51, 65.27, 125.08, 140.93, 171.10

[0220]



[0221]

^{1}H-NMR, δ: 0.89 (t, J=6.9 Hz, 3H)
1.31 (m, 9H)
1.45 (m, 2H)
1.90 (br s, OH)
2.22 (d/t, J=7.5, 7.2 Hz, 2H)
2.60 (t, J=6.6 Hz, 2H)
3.69 (t, J=6.6 Hz, 2H)
4.20 (q, J=6.9 Hz, 2H)
6.89 (t, J=7.5 Hz, 1H)

[0222]

Reaction product in Example 9-5

^{1}H-NMR, δ: 0.14 (s, 9H)
1.92 (t/t, J=6.6, 5.4 Hz, 2H)
2.65 (t, J=6.6 Hz, 2H)
4.30 (t/d, J=5.4, 2.1 Hz, 2H)

7.18 (t, J=2.1 Hz, 1H)

^{13}C-NMR, δ: -1.49, 23.21, 27.78, 69.00, 139.86, 145.62, 165.60

[0223]

Reaction product in Example 9-6

^{1}H-NMR, δ: 0.37 (s, 9H)
2.04 (m, 2H)
2.74 (m, 2H)
4.2 (m, 2H)

^{13}C-NMR, δ: 1.50, 23.07, 28.77, 66.49, 113.87, 144.69, 167.30

[0224]

Reaction product in Example 9-7

^{1}H-NMR, δ: 1.02 (t, J=7.5 Hz, 3H)
1.91 (t/t, J=6.3, 5.7 Hz, 2H)
2.13 (d/q, J=7.5, 7.5 Hz, 2H)
2.50 (m, 2H)
4.28 (t, J=5.7 Hz, 2H)
7.00 (m, 1H)

^{13}C-NMR, δ: 12.39, 21.43, 22.48, 23.28, 68.36, 124.79, 147.59, 166.50

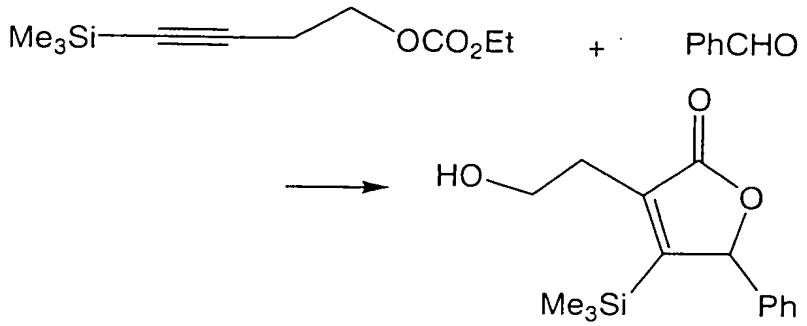
[0225]

Reaction product in Example 9-9

^{1}H-NMR, δ: 0.19 (s, 9H)
1.30 (t, J=6.9 Hz, 3H)
1.45-1.70 (m, 4H)
2.09 (br s, OH)
2.41 (m, 2H)
3.66 (t, J=6.0 Hz, 2H)
4.19 (q, J=6.9 Hz, 2H)
6.81 (s, 1H)

Example 9-11

[0226]



[0227]

To 7.5 ml of ethyl ether solution containing 369 ml (1.3 mmol) of tetraisopropoxytitanium and 1.0 mmol of 1-trimethylsilyl-1-butyne-4-carbonate was added dropwise at -50°C 2 ml of 1.3M ethyl ether solution containing isopropylmagnesium bromide (2.6 mmol). The reaction liquid was stirred at -45 to -40°C for 1 hour. The reaction liquid was given 212 mg (2 mmol) of benzaldehyde at -40°C. The reaction liquid was heated to 0°C over 1 hour, given 5 ml of 1N hydrochloric acid, heated to room temperature, and stirred for 30 minutes. After layer separation, the organic layer was washed with a saturated aqueous solution of sodium hydrogen carbonate, dried with anhydrous magnesium sulfate, and freed of solvent by vacuum distillation. The residues were purified by silica gel chromatography. Thus there was obtained a product in cyclized form in a yield of 65%.

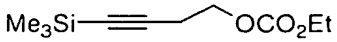
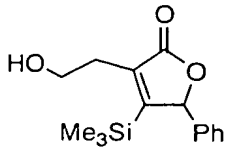
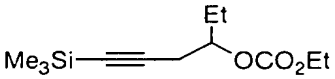
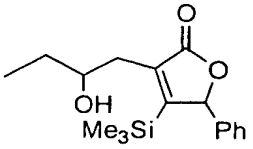
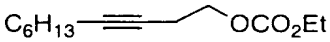
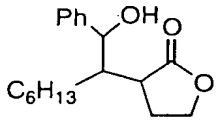
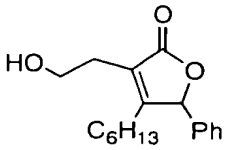
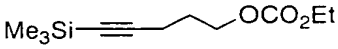
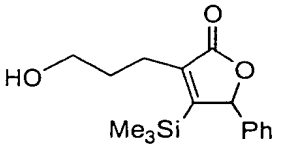
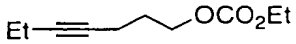
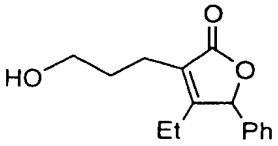
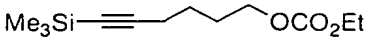
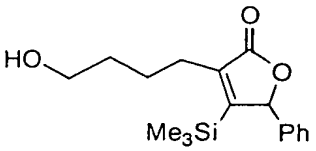
[0228]

Example 9-11 to 9-16

The procedure of Example 9-11 was repeated except that the 1-trimethylsilyl-1-butyne-4-carbonate was replaced by those shown in Table 15. There were obtained corresponding products cyclized form in respective yields as shown in Table 15.

[0229]

Table 15

Example	Acetylene compound	Reaction product	Yields (%)
9-11			65
9-12			50
9-13			56
			12
9-14			70
9-15			74
9-16			69

[0230]

Reaction product in Example 9-11

^{1}H-NMR, δ: 0.04 (s, 9H)
2.77 (t, J=5.8 Hz, 2H)
3.87 (t, J=5.8 Hz, 2H)
5.88 (s, 1H)
7.17 (m, 2H)
7.36 (m, 3H)

^{13}C-NMR, δ: -1.09, 29.87, 61.12, 87.65, 128.00, 128.81, 129.52, 134.81, 138.44, 164.98, 175.10

[0231]

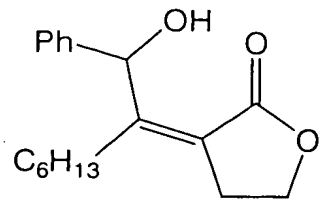
Reaction product in Example 9-12

^{1}H-NMR, δ: 0.02 (s, 9H)
1.01 (t, J=6.0 Hz, 3H)
1.58 (m, 2H)
2.56 (d/d, J=11.7, 6.6 Hz, 1H)
2.70 (d, J=11.7 Hz, 1H)
2.75 (br s, OH)
3.86 (m, 1H)
5.88 (s, 1H)
7.20 (m, 2H)
7.36 (m, 3H)

^{13}C-NMR, δ: -1.09, 10.00, 30.89, 34.04, 71.76, 87.78, 128.04, 128.82, 129.51, 134.89, 138.70, 164.83, 175.30

Reaction product in Example 9-13

[0232]

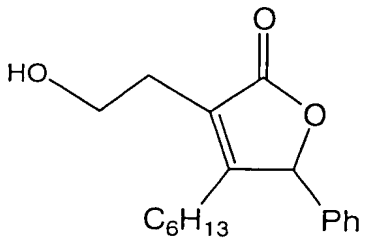


[0233]

^{1}H-NMR, δ: 0.88 (t, J=6.8 Hz, 3H)
1.23 (m, 6H)
1.42 (m, 2H)
2.13 (t, J=7.5 Hz, 2H)
2.96 (m, 2H)
4.13 (d, J=6.0 Hz, OH)
4.40 (t, J=7.5 Hz, 2H)
6.43 (d, J=6.0 Hz, 1H)
7.20-7.50 (m, 5H)

^{13}C-NMR, δ: 13.94, 22.41, 27.71, 27.77, 29.69, 31.31, 32.99, 65.45, 71.22, 120.78, 126.11, 127.38, 128.23, 141.65, 159.36, 171.32

[0234]



[0235]

^{1}H-NMR, δ: 0.88 (t, J=6.8 Hz, 3H)
1.23 (m, 6H)
1.40 (m, 2H)
2.00 (m, 1H)
2.39 (m, 1H)
2.62 (t, J=6.0 Hz, 2H)
3.86 (t, J=6.0 Hz, 2H)
5.75 (s, 1H)
7.21 (m, 2H)
7.40 (m, 3H)

[0236]

Reaction product in Example 9-14

^{1}H-NMR, δ: 0.01 (s, 9H)
1.84 (t/t, J=7.5, 6.0 Hz, 2H)
2.57 (t, J=7.5 Hz, 2H)

2.70 (br s, OH)
3.69 (t, J=6.0 Hz, 2H)
5.81 (s, 1H)
7.14 (m, 2H)
7.33 (m, 3H)

^{13}C-NMR, δ: -1.19, 22.21, 32.23, 61.42, 87.21, 127.88, 128.74, 129.41, 134.98, 140.94, 163.18, 175.00

[0237]

Reaction product in Example 9-15

^{1}H-NMR, δ: 0.98 (t, J=7.8 Hz, 3H)
1.81 (t/t, J=7.5, 6.0 Hz, 2H)
2.02 (d/q, J=15.6, 7.8 Hz, 1H)
2.45 (d/q, J=15.6, 7.8 Hz, 1H)
2.47 (t, J=7.5 Hz, 2H)
2.78 (br s, OH)
3.67 (t, J=6.0 Hz, 2H)
5.75 (s, 1H)
7.20 (m, 2H)
7.38 (m, 3H)

^{13}C-NMR, δ: 12.31, 19.43, 19.72, 31.13, 61.16, 83.86, 126.07, 126.84, 128.86, 129.22, 134.62, 165.41, 175.00

[0238]

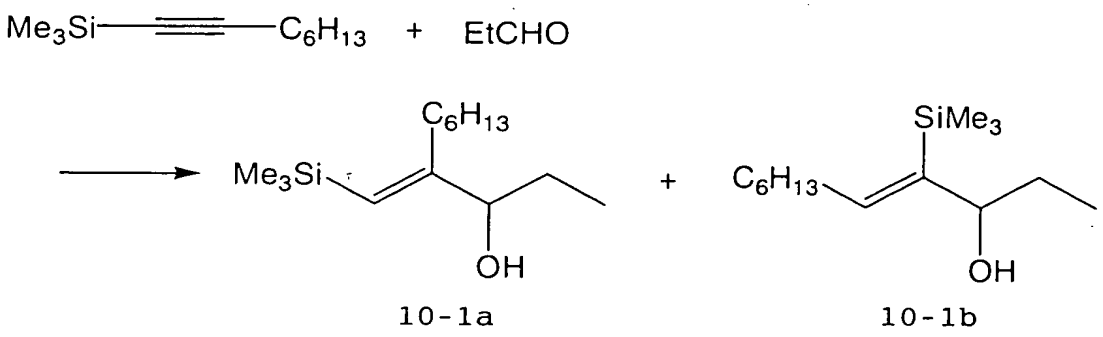
Reaction product in Example 9-16

^{1}H-NMR, δ: 0.06 (s, 9H)
1.71 (m, 4H)
1.89 (br s, OH)
2.52 (m, 2H)
3.76 (m, 2H)
5.82 (s, 1H)
7.17 (m, 2H)
7.38 (m, 3H)

^{13}C-NMR, δ: -1.09, 25.50, 25.94, 32.53, 62.33, 86.94, 127.92, 128.77, 129.42, 135.21, 141.36, 162.10, 174.50

Example 10-1

[0239]



10-1a 10-1b

[0240]

In 10 ml of ether were dissolved 0.75 ml (1.5 mmol) of trimethoxychlorotitanium (as 2M ether solution) and 0.219 ml (1.2 mmol) of 1-trimethylsilyl-1-octyne. To the solution (cooled to -78°C) was added dropwise 1.97 ml of 1.52M ether solution containing 3 mmol of isopropylmagnesium bromide. The reaction liquid was heated to -30°C and stirred for 5 hours. The reaction liquid was cooled again to -78°C and given 0.066 ml (0.9 mmol) of propanal, followed by stirring for 1 hour. The reaction liquid was stirred with 20 ml of 1N hydrochloric acid at room temperature for 30 minutes. After extraction with 30 ml of ether, the organic layer was dried with anhydrous magnesium sulfate and freed of solvent by vacuum distillation. The residues were purified by silica gel chromatography. Thus there was obtained a mixture of adducts (10-1a + 10-1b) in a yield of 35%.

[0241]

This mixture was dissolved in 1 ml of tetrahydrofuran, and the solution was stirred together with a catalytic amount of potassium hydride at 0°C for 1 hour. The solution was given 3 ml of aqueous solution of ammonium chloride and extracted with ether. The organic layer was dried with anhydrous magnesium sulfate and freed of solvent by vacuum distillation. The residues were purified by silica gel chromatography. Thus there was isolated 10-1a.

It was found to have an optical rotation $[\alpha]_D$ = 1.7° and an optical purity of 20 %ee (by ^{1}H-NMR of its MTPA ester).

[0242]

Examples 10-2 to 10-6

The procedure of Example 10-1 was repeated except that the trimethoxychlorotitanium and propanal were replaced by those shown in Tables 16 and 17. There were obtained mixtures of corresponding adducts whose ratio, yield, optical rotation, and optical purity are shown in Tables 16 and 17.

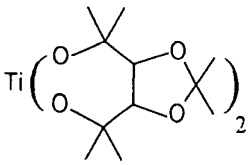
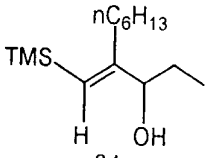
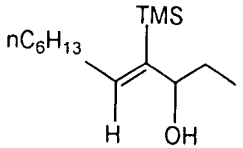
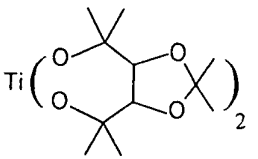
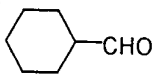
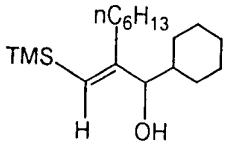
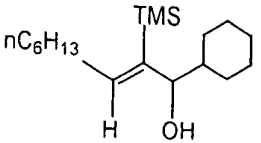
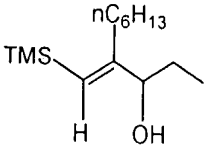
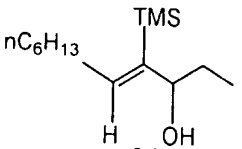
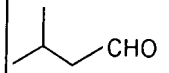
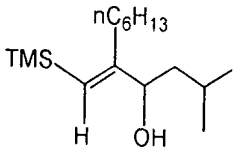
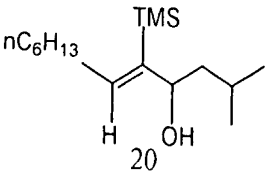
[0243]

Table 16

Example	Titanium compound	Aldehyde	Reaction product (ratio) a	b	Yields of mixture (%)	Reaction product a: Optical rotation ([α]D)	Reaction product a: Optical purity (%ee)
10-1		EtCHO			35	1.7	20
10-2					26	1.0	12
10-3		EtCHO			31	-3.2	62

[0244]

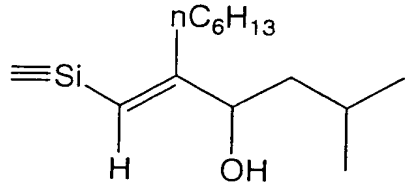
Table 17

Example	Titanium compound	Aldehyde	Reaction product (ratio) a	Reaction product (ratio) b	Yields of mixture (%)	Reaction product a: Optical rotation ([α]D)	Reaction product a: Optical purity (%ee)
10-4		EtCHO	 84	 16	8	-	-
10-5			 81	 19	21	-	62
10-6	ClTi(Menthol(+))	EtCHO	 64	 26	9	-	-
			 80	 20	15	23	14

Reaction product in Example 10-1

[0245]

a

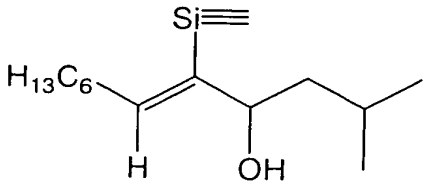


[0246]

^{1}H-NMR, δ: 5.45 (s, 1H)
3.79 (t, J=4.8 Hz, 1H)
2.12-2.25 (m, 1H)
1.92-2.05 (m, 1H)
1.72-1.88 (m, 1H)
1.55-1.20 (m, 11H)
1.05-0.80 (m, 9H)
0.11 (s, 9H)

[0247]

b

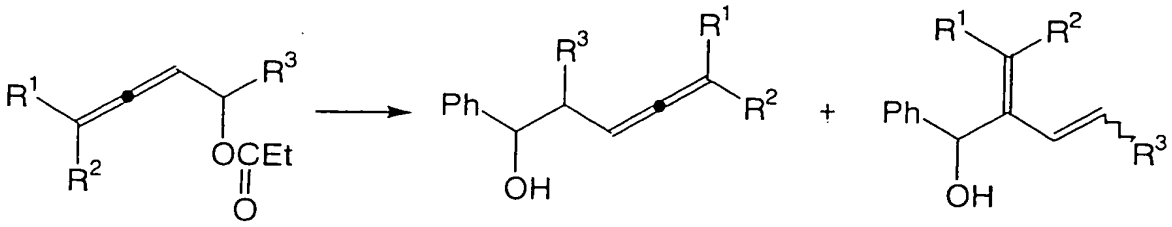


[0248]

^{1}H-NMR, δ: 5.58-5.30 (m, 2H)
3.68 (t, J=7.5 Hz, 1H)
2.10-1.95 (m, 2H)
1.70-1.50 (m, 1H)
1.45-1.20 (m, 10H)
1.00-0.80 (m, 9H)
0.08 (s, 9H)

Examples 11-1 to 11-4

[0249]



11A 11B 11C

[0250]

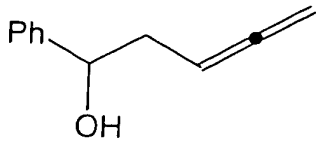
To an ethyl ether solution (10 ml) containing allenyl alcohol derivative 11A (1.0 mmol) and tetraisopropoxytitanium (0.296 ml, 1.0 mmol) was added isopropylmagnesium bromide (2.0 mmol) in ethyl ether solution at -60° C. The reaction liquid was stirred at -50 to -40° C for 1.5 hours. The reaction liquid was given benzaldehyde (74 mg, 0.7 mmol) at -40° C and then heated to room temperature over 1 hour. After mixing with 5 ml of 3N hydrochloric acid, the reaction liquid was separated into layers. The organic layer was dried with anhydrous magnesium sulfate and freed of solvent by vacuum distillation. The residues were purified by silica gel chromatography. Thus there were obtained reaction products in allene form 11B and diene form 11C in yields as shown in Table 18.

[0251]

Table 18

Example	11A			Yields (%)		Recovered 11A
	R^1	R^2	R^3	11B	11C	
11-1	H	H	H	22	22	40
11-2	Et	H	H	30	40(E/Z=1/3)	15
11-3	H	H	Et	28	41(E only)	13
11-4	$-(C_2H)_5-$		H	18	58	28

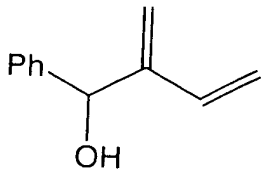
[0252]



[0253]

^{1}H-NMR, δ: 2.40-2.51 (m, 2H)
4.66-4.80 (m, 2H)
4.75 (t, J=6.3 Hz, 1H)
7.22-7.43 (m, 5H)

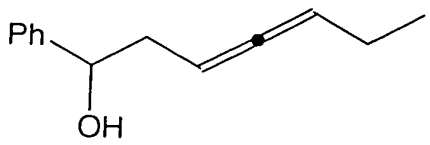
[0254]



[0255]

^{1}H-NMR, δ: 5.04 (d, J=11.3 Hz, 1H)
5.21 (d, J=17.9 Hz, 1H)
5.33 (br s, 1H)
5.40 (d, J=1.2 Hz, 1H)
5.46 (br s, 1H)
6.31 (dd, J=11.3, 17.9 Hz, 1H)
7.22-7.43 (m, 5H)

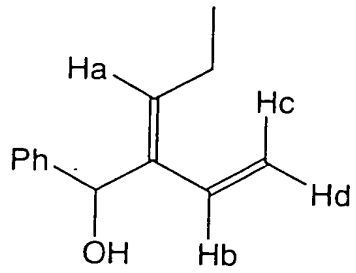
[0256]



[0257]

^{1}H-NMR, δ: 0.96 (t, J=7.9 Hz, 3H)
1.89-2.08 (m, 2H)
2.39-2.49 (m, 2H)
4.74 (t, J=6.4 Hz, 1H)
5.05-5.20 (m, 2H)
7.15-7.42 (m, 5H)

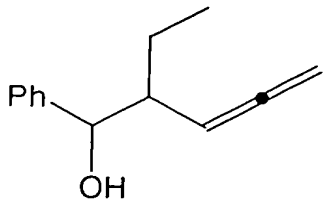
[0258]



[0259]

^{1}H-NMR, δ: 0.92-1.02 (m, 3H)
1.88-2.08 (m, 2H)
(Hd)5.09 (d, J=12.5 Hz, 1H)
(Hc)5.17 (d, J=18.4 Hz, 1H)
5.47 (br s, 1H)
(Ha)5.79 (t, J=7.5 Hz, 1H)
(Hb)6.53 (dd, J=12.5, 18.4 Hz, 1H)
7.15-7.42 (m, 5H)

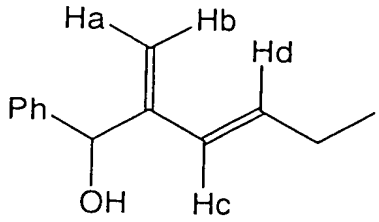
[0260]



[0261]

^{1}H-NMR, δ: 0.94 (t, J=7.2 Hz, 3H)
1.55-2.25 (m, 3H)
4.63 (d, J=9.8 Hz, 1H)
4.65-4.80 (m, 2H)
4.93-5.03 (m, 1H)
7.15-7.43 (m, 5H)

[0262]

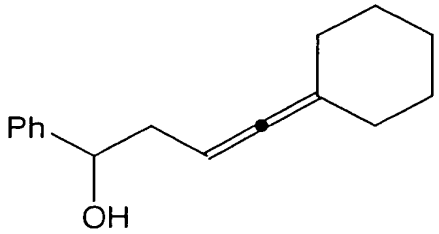


(trans)

[0263]

^{1}H-NMR, δ: 0.86 (t, J=6.4 Hz, 3H)
1.95-2.08 (m, 2H)
(Ha, Hb) 5.18 (br s, 1H), 5.22 (br s, 1H),
5.40 (br s, 1H)
(Hd) 5.76 (dt, J=16.3, 6.8 Hz, 1H)
(Hc) 5.97 (d, J=16.3 Hz, 1H)
7.15-7.43 (m, 5H)

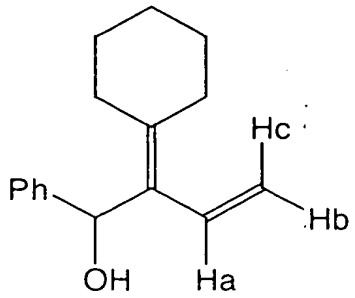
[0264]



[0265]

^{1}H-NMR, δ: 1.22-1.79 (m, 10H)
1.81-1.95 (m, 2H)
4.72 (t, J=6.8 Hz, 1H)
4.91-4.99 (m, 1H)
7.15-7.42 (m, 1H)

[0266]

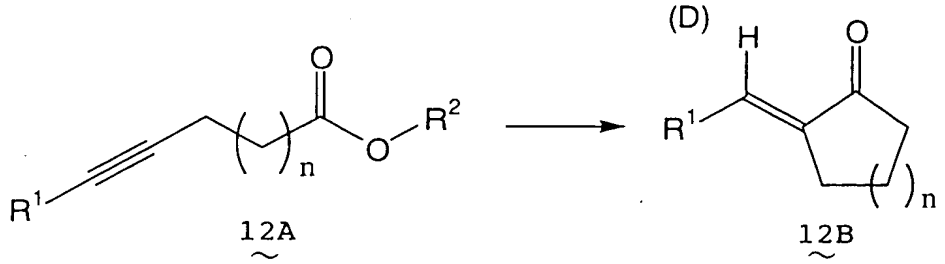


[0267]

^{1}H-NMR, δ: 1.22-1.79 (m, 10H)
(Hc) 5.02 (d, J=16.9 Hz, 1H)
(Hb) 5.12 (d, J=12.0 Hz, 1H)
5.89 (br s, 1H)
(Ha) 6.37 (dd, J=12.0, 16.9 Hz, 1H)
7.15-7.42 (m, 5H)

Examples 12-1 to 12-8

[0268]

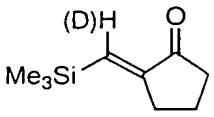
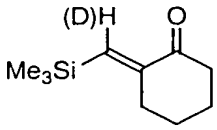
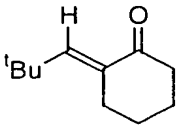
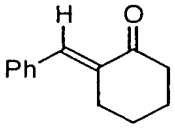
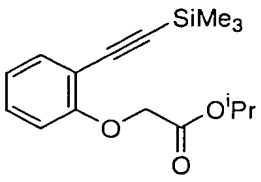
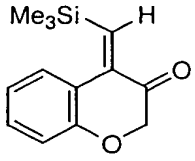


[0269]

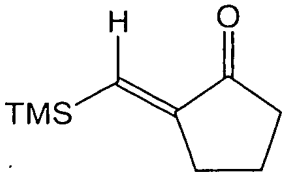
To an ethyl ether solution (10 ml) containing acetylene carboxylate ester 12A (1.0 mmol) and triisopropoxychlorotitanium (1.5 mmol) was added at -78°C an ethyl ether solution containing isopropylmagnesium bromide (3.0 mmol). The reaction liquid was stirred at -50 to -45°C for 2 hours. The reaction liquid was given 0.3 ml of a saturated aqueous solution of sodium hydrogen carbonate and heated to room temperature. The reaction liquid was stirred together with 1 g each of sodium fluoride and celite. After filtration, the filtrate was concentrated under reduced pressure and the residues were purified by silica gel chromatography. There were obtained samples of 12B (cyclized form) in respective yields shown in Table 19. (In Table 19, D denotes a deuterium atom. Termination with heavy water in place of water gives rise to products in deuterio form.)

[0270]

Table 19

Example	12A			12B	
				Yields (%)	Deuterio form (%)
12-1	R^1=Me_3Si	R^2=Me	n=2		18-35
12-2	Me_3Si	Et	2	"	25
12-3	Me_3Si	^iPr	2	"	72 (98%D)
12-4	Me_3Si	^tBu	2	"	12
12-5	Me_3Si	^iPr	3		79 (98%D)
12-6	^tBu	^iPr	3		70
12-7	Ph	^iPr	3		68
12-8					72

[0271]

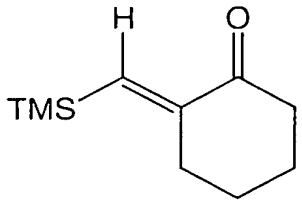


(Yield 72%)
(98%D)

[0272]

^{1}H-NMR, δ: 0.15 (s, 9H)
1.86-2.00 (m, 2H)
2.31 (t, J=7.9 Hz, 2H)
2.68 (dt, J=2.6, 7.3 Hz, 2H)
6.65 (t, J=2.6 Hz, 1H)

[0273]



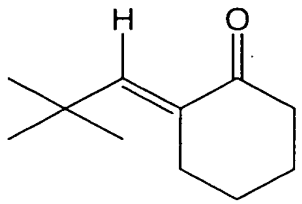
(Yield 79%)
(98%D)

[0274]

^{1}H-NMR, δ: 0.15 (s, 9H)
1.69-1.96 (m, 4H)
2.45 (t, J=6.5 Hz, 2H)
2.62 (t, J=6.2 Hz, 2H)
6.56 (br s, 1H)

^{13}C-NMR, δ: -0.7, 23.8, 24.3, 32.1, 40.4, 136.3, 151.8, 201.3

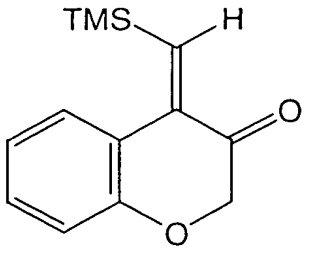
[0275]



[0276]

^{1}H-NMR, δ: 0.16 (s, 9H)
1.68-1.91 (m, 4H)
2.43 (t, J=6.7 Hz, 2H)
2.67 (dt, J=2.0, 6.5 Hz, 2H)
6.57 (t, J=2.0 Hz, 1H)

[0277]



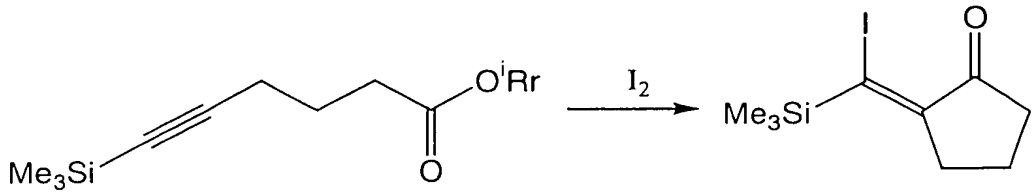
(Yield 72%)

[0278]

^{1}H-NMR, δ: 0.21 (s, 9H)
4.55 (s, 2H)
7.00 (s, 1H)
7.02-7.12 (m, 2H)
7.31 (t, J=7.8 Hz, 1H)
7.42 (d, J=7.8 Hz, 1H)

Example 12-9

[0279]



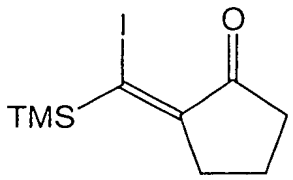
12C 12D

[0280]

To an ethyl ether solution (10 ml) containing acetylene carboxylate ester 12C (1.0 mmol) and triisopropoxychlorotitanium (1.5 mmol) was added at -78°C an ethyl ether solution containing isopropylmagnesium bromide (3.0 mmol). The reaction liquid was stirred at -50 to -45°C for 2 hours. The reaction liquid was given an ethyl ether solution (5 ml) of iodine (3.0 mmol). The reaction liquid was heated to 0°C over 1.5 hours. With 5 ml of 3N hydro-chloric acid added, the reaction liquid was separated into layers. The organic layer was dried with anhydrous magnesium sulfate and freed of solvent by vacuum distillation. The residues were purified by silica gel

chromatography. There was obtained 12D in iodated form (yield: 56%).

[0281]

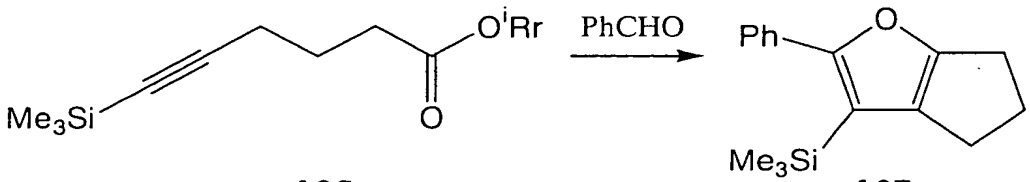


(Yield 59%)

^{1}H-NMR, δ: 0.32 (s, 9H)
1.70-1.86 (m, 2H)
2.41 (t, J=8.0 Hz, 2H)
2.76 (t, J=7.6 Hz, 2H)

Example 12-10

[0282]

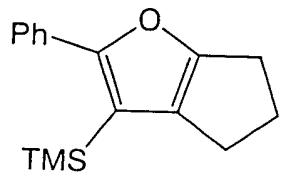


12C 12E

[0283]

To an ethyl ether solution (10 ml) containing acetylene carboxylate ester 12C (1.0 mmol) and triisopropoxychlorotitanium (1.5 mmol) was added at -78°C an ethyl ether solution containing isopropylmagnesium bromide (3.0 mmol). The reaction liquid was stirred at -50 to -45°C for 2 hours. The reaction liquid was given benzaldehyde (1.5 mmol). The reaction liquid was heated to 0°C over 1.5 hours. With 5 ml of 3N hydrochloric acid added, the reaction liquid was separated into layers. The organic layer was dried with anhydrous magnesium sulfate and freed of solvent by vacuum distillation. The residues were purified by silica gel chromatography. There was obtained 12E in furan form (yield: 62%).

[0284]



[0285]

^{1}H-NMR, δ: 0.21 (s, 9H)
2.38-2.53 (m, 2H)
2.57-2.82 (m, 4H)
7.10-7.65 (m, 5H)

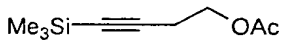
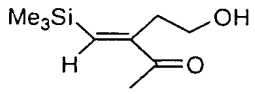
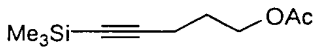
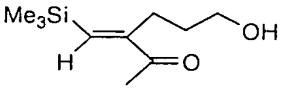
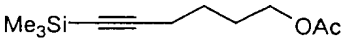
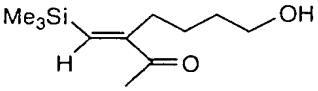
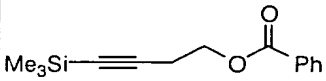
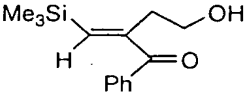
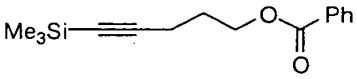
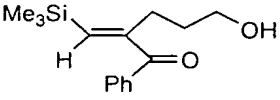
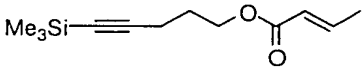
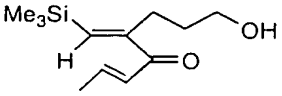
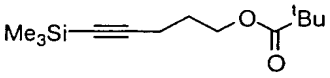
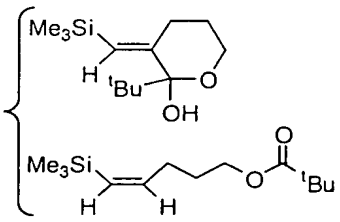
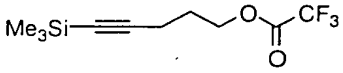
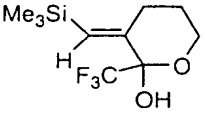
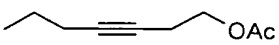
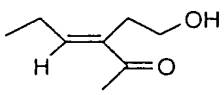
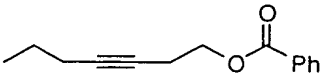
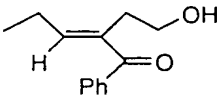
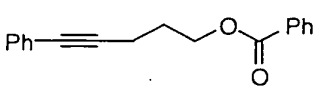
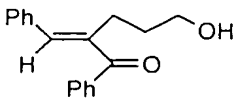
[0286]

Examples 13-1 to 13-11

To an ethyl ether solution (4.6 mmol) containing any of 11 kinds of acetylene carboxylate ester 13A (1.0 mmol) shown in Table 20 and triisopropoxychlorotitanium (2.3 mmol) was added at -78°C an ethyl ether solution containing isopropylmagnesium bromide (4.6 mmol). The reaction liquid was stirred at -50 to -45°C for 2 hours. With 5 ml of 3N hydrochloric acid added, the reaction liquid was separated into layers. The organic layer was dried with anhydrous magnesium sulfate and freed of solvent by vacuum distillation. The residues were purified by silica gel chromatography. There were obtained samples of 13B in α,β-unsaturated ketone form in respective yields as shown in Table 20. In the case where heavy water was added in place of 3N hydrochloric acid, there were obtained compounds having a deuterium atom in the same yield.

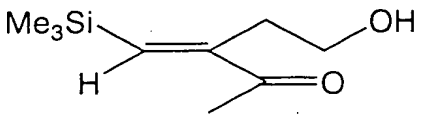
[0287]

Table 20

Example	13A	13B	Yields (%)
13-1			69
13-2			58
13-3			47
13-4			76
13-5			77
13-6			38
13-7			39.5 23.5
13-8			48
13-9			22
13-10			61
13-11			

Reaction product in Example 13-1

[0288]



[0289]

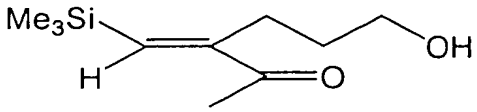
^{1}H-NMR, δ: 0.11 (s, 9H)
2.35 (s, 3H)
2.61 (t, J=6.35 Hz, 2H)
3.62 (t, J=6.32 Hz, 2H)
6.77 (s, 1H)

^{13}C-NMR, δ: -0.29 (3C), 25.8, 34.1, 62.8, 144.6, 153.3, 202.0

IR: 3430, 2950, 1670, 1600, 1360, 1250, 850 (cm^{-1})

Reaction product in Example 13-2

[0290]



[0291]

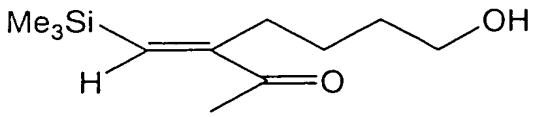
^{1}H-NMR, δ: 0.20 (s, 9H)
1.57-1.62 (m, 2H)
2.34 (s, 3H)
2.42 (t, J=7.57 Hz, 2H)
3.56 (t, J=6.21 Hz, 2H)
6.69 (s, 1H)

^{13}C-NMR, δ: -0.36 (3C), 25.7, 26.4, 33.2, 62.0, 142.7, 155.9, 201.0

IR: 3400, 2930, 1660, 1580, 1360, 1240, 840 (cm^{-1})

Reaction product in Example 13-3

[0292]



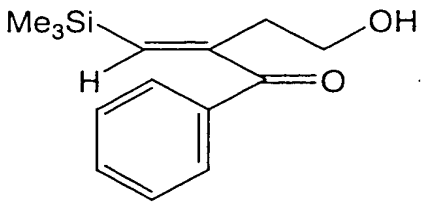
[0293]

^{1}H-NMR, δ: 0.16 (s, 9H)
1.30-1.41 (m, 2H)
1.54 (tt, J=6.90 Hz, 2H)
2.29 (s, 3H)
2.31 (t, J=7.58 Hz, 2H)
3.60 (t, J=6.53 Hz, 2H)
6.59 (s, 1H)

^{13}C-NMR, δ: -0.39 (3C), 25.8, 26.1, 30.3, 32.6, 62.6, 141.4, 156.4, 200.6

Reaction product in Example 13-4

[0294]



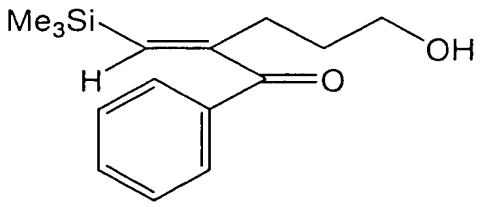
[0295]

^{1}H-NMR, δ: 0.21 (s, 9H)
2.80 (t, J=6.08 Hz, 2H)
3.77 (t, J=6.05 Hz, 2H)
6.30 (s, 1H)

^{13}C-NMR, δ: -0.15 (3C), 35.6, 62.7, 128.2, 129.9, 132.4, 137.3, 144.3, 152.5, 200.0

Reaction product in Example 13-5

[0296]



[0297]

^{1}H-NMR, δ: 0.19 (s, 9H)
1.65-1.75 (m, 2H)
2.65 (t, J=7.67 Hz, 2H)
3.62 (t, J=6.32 Hz, 2H)

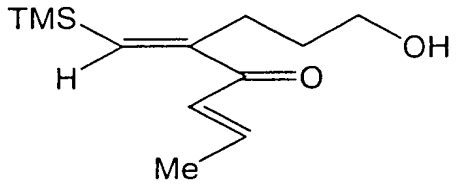
6.18 (s, 1H)
7.38-7.44 (m, 2H)
7.48-7.54 (m, 1H)
7.69-7.72 (m, 2H)

^{13}C-NMR, δ: -0.29 (3C), 28.2, 32.4, 62.1, 128.1, 129.6, 132.1, 137.6, 142.2, 154.9, 199.3

IR: 3380, 2920, 1650, 1600, 1450, 1240, 1060, 850 (cm^{-1})

Reaction product in Example 13-6

[0298]



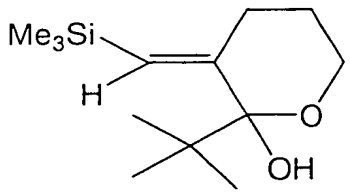
[0299]

^{1}H-NMR, δ: 0.21 (s, 9H)
1.59-1.68 (m, 2H)
1.92 (dd, J=6.44, 1.5 Hz, 3H)
2.52 (t, J=7.41 Hz, 2H)
3.57 (t, J=6.18 Hz, 2H)
6.55 (s, 1H)
6.69 (dd, J=15.2, 1.5 Hz, 1H)
6.82-6.54 (m, 1H)

^{13}C-NMR, δ: -0.25 (3C), 18.4, 27.1, 32.9, 62.0, 127.3, 140.3, 143.8, 156.4, 193.4

Reaction product in Example 13-7-1

[0300]



[0301]

^{1}H-NMR, δ: 0.17 (s, 9H)
1.22 (s, 9H)
1.57-1.63 (m, 2H)
2.42 (t, J=7.82 Hz, 2H)

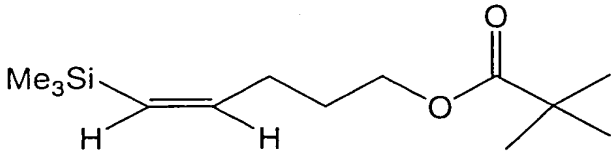
3.61 (t, J=6.24 Hz, 2H)
5.76 (s, 1H)

^{13}C-NMR, δ: -0.02 (3C), 28.2 (3C), 30.3, 32.4, 43.6 (1C), 62.3, 131.2, 156.7, 213.8

IR: 3430, 2960, 1680, 1600, 1260, 1140, 860 (cm^{-1})

Reaction product in Example 13-7-2

[0302]



[0303]

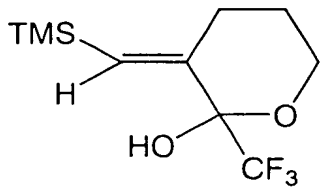
^{1}H-NMR, δ: 0.11 (s, 9H)
1.20 (s, 9H)
1.62-1.76 (m, 2H)
2.20 (dt, J=6.51, 7.47 Hz, 2H)
4.06 (t, J=6.50 Hz, 2H)
5.52 (d, J=1.40 Hz, 1H)
6.28 (dt, J=14.1, 7.2 Hz, 1H)

^{13}C-NMR, δ: 0.15 (3C), 27.2 (3C), 28.9, 30.0, 38.7 (1C), 64.0, 130.0, 147.5, 178.5

IR: 2940, 1720, 1600, 1480, 1280, 1240, 1150, 840 (cm^{-1})

Reaction product in Example 13-8

[0304]



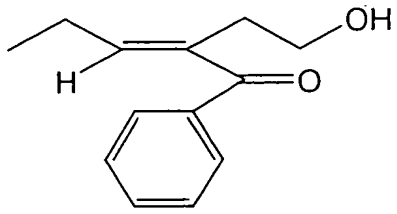
[0305]

^{1}H-NMR, δ: 0.16 (s, 9H)
1.65-1.78 (m, 1H)
1.94-2.08 (m, 1H)
2.55-2.63 (m, 1H)
2.94 (s, 1H)
6.05 (s, 1H)

^{13}C-NMR, δ: 0.28, 24.9, 26.4, 61.2, 120.7, 124.6, 131.3, 146.9

Reaction product in Example 13-10

[0306]



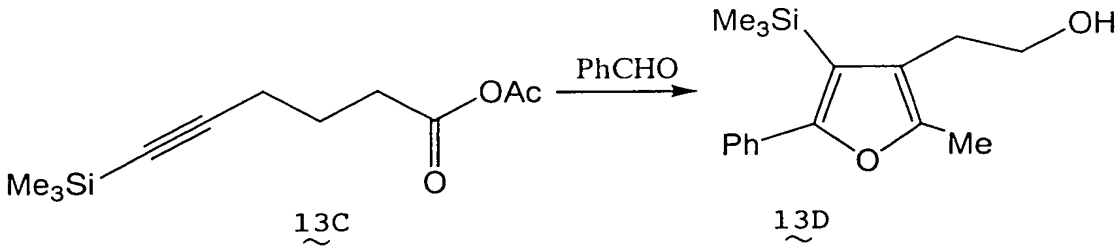
[0307]

^{1}H-NMR, δ: 1.06 (t, J=7.56 Hz, 3H)
2.34 (dt, J=15.2, 7.5 Hz, 2H)
2.72 (t, J=6.08 Hz, 2H)
3.76 (t, J=6.06 Hz, 2H)
6.35 (t, J=7.41 Hz, 1H)

^{13}C-NMR, δ: 13.3, 22.3, 30.6, 62.3, 128.1, 129.6, 131.9, 137.5, 138.2, 150.0, 200.2

Example 13-12

[0308]



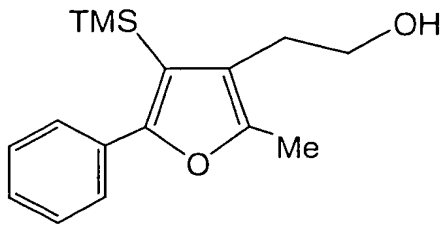
13C 13D

[0309]

To an ethyl ether solution (10 ml) containing acetylene alcohol ester 13C (1.0 mmol) and triisopropoxychlorotitanium (2.3 mmol) was added at -78°C an ethyl ether solution containing isopropylmagnesium bromide (4.6 mmol). The reaction liquid was stirred at -50 to -45°C for 1 hour. The reaction liquid was given 74 mg (0.7 mmol) of benzaldehyde at -40°C and heated to 0°C over 1 hour. With 5 ml of 3N hydrochloric acid added, the reaction liquid was separated into layers. The organic layer was dried with

anhydrous magnesium sulfate and freed of solvent by vacuum distillation. The residues were purified by silica gel chromatography. There was obtained 13D in furan form (yield: 62%).

[0310]



[0311]

^{1}H-NMR, δ: 0.16 (s,9H)
2.31 (s, 3H)
2.74 (t, J=6.98Hz, 2H)
3.76 (t, J=6.89Hz, 2H)
7.34-7.41 (m, 3H)
7.44-7.47 (m, 2H)

^{13}C-NMR, δ: 1.11(3C), 11.5, 29.0, 63.1, 114.9, 120.5, 127.8(2C), 128.1, 129.1(2C), 133.4, 148.9, 158.0

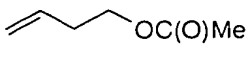
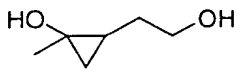
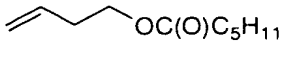
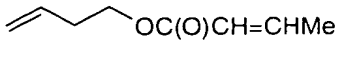
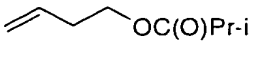
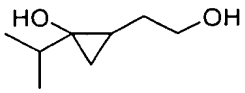
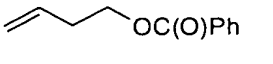
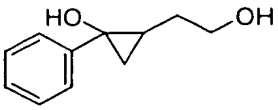
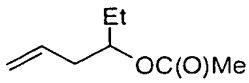
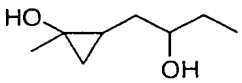
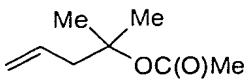
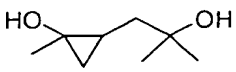
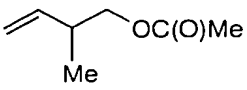
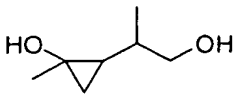
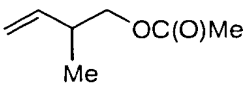
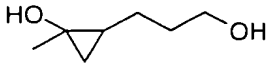
[0312]

Examples 14-11 to 14-9

To an ethyl ether solution (7 ml) containing any of 9 kinds of olefin ester 14A (1.0 mmol) shown in Table 21 and tetraisopropoxytitanium (2.0 mmol) was added at -50°C an ethyl ether solution containing isopropylmagnesium bromide (4.0 mmol). The reaction liquid was stirred at -45 to -40°C for 2 hours. The reaction liquid was heated to 0°C and stirred for 2 hours. With 5 ml of 3N hydrochloric acid added, the reaction liquid was separated into layers. The organic layer was dried with anhydrous magnesium sulfate and freed of solvent by vacuum distillation. The residues were purified by silica gel chromatography. There were obtained samples of 14B in cyclopropane form in respective yields as shown in Table 21.

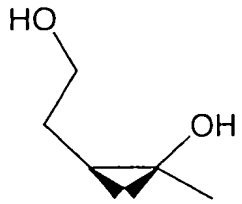
[0313]

Table 21

Example	14A	14B	Yields (%)	Z/E
14-1			93	58:42
14-2			95	88:12
14-3			78	93:7
14-4			88	88:12
14-5			85	>97:3
14-6			33 (70)	41:59 (95:5)
14-7			28 (78)	47:53 (91:9)
14-8			74	>97:3
14-9			25	73:27

*Values in parentheses are those which were obtained in the case where the reaction liquid was stirred at 0°C, heated to 20°C, and stirred again for 3.5 hours.

[0314]

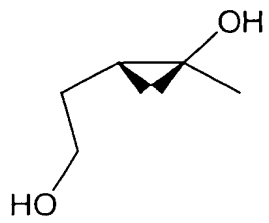


[0315]

^{1}H-NMR, δ: 0.41 (m, 1H)
0.65 (m, 2H)
1.40 (s, 3H)
1.57 (m, 1H)
2.00 (m, 1H)
3.65 (m, 1H)
3.80 (m, 1H)

^{13}C-NMR, δ: 19.99, 23.09, 25.86, 31.19, 54.07, 62.43

[0316]

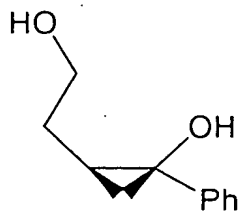


[0317]

^{1}H-NMR, δ: 0.13 (d/d, J=6.0, 6.0 Hz, 1H)
0.89 (d/d, J=10.2, 6.0 Hz, 1H)
1.05 (m, 1H)
1.43 (s, 3H)
1.51 (d/t, J=6.2, 6.2 Hz, 2H)
2.90 (br s, 2H)
3.70 (t, J=6.2 Hz, 2H)

^{13}C-NMR, δ: 19.62, 20.62, 22.09, 32.74, 54.91, 62.39

[0318]



[0319]

^{1}H-NMR, δ: 0.93 (d/d, J=5.8, 5.8 Hz, 1H)
1.18 (m, 1H)
1.27 (d/d, J=10.2, 5.8 Hz, 1H)
1.72 (m, 1H)
2.12 (m, 1H)
3.64 (m, 1H)
3.80 (m, 1H)
7.15-7.35 (m, 5H)

^{13}C-NMR, δ: 23.31, 31.18, 27.57, 57.83, 62.45, 124.05, 125.91, 128.15, 145.82

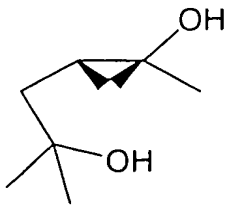
[0320]

[0321]

^{1}H-NMR, δ: 0.43 (d/d, J=5.8, 5.8 Hz, 1H)
0.65 (d/d, J=9.6, 5.8 Hz, 1H)
0.74 (m, 1H)
1.28 (s, 3H)
1.33 (s, 3H)
1.44 (s, 3H)
1.52 (d/d, J=15.0, 10.3 Hz, 1H)
1.92 (d/d, J=15.0, 5.1 Hz, 1H)

^{13}C-NMR, δ: 20.57, 20.93, 26.02, 28.16, 31.32, 42.00, 54.14, 71.37

[0322]



[0323]

^{1}H-NMR, δ: 0.17 (d/d, J=6.0, 6.0 Hz, 1H)
0.97 (d/d, J=10.2, 6.0 Hz, 1H)
1.10 (m, 1H)
1.2-1.35 (s, 7H)
1.42 (s, 3H)
1.65 (d/d, J=13.8, 5.7 Hz, 1H)
1.8-2.5 (m, 2H)

^{13}C-NMR, δ: 20.48, 20.90, 21.31, 29.50, 29.13, 43.36, 54.82, 71.33

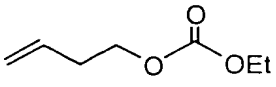
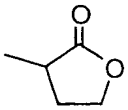
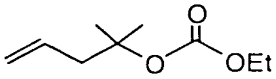
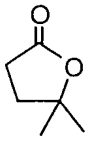
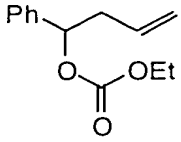
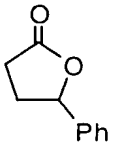
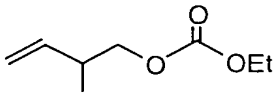
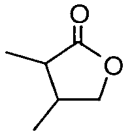
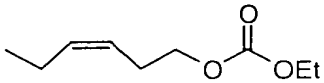
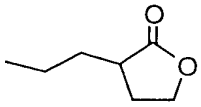
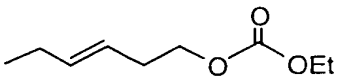
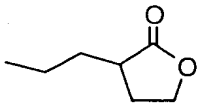
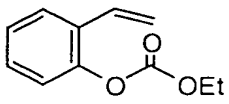
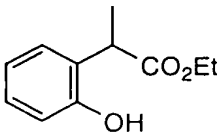
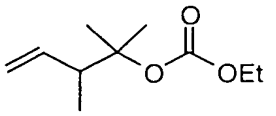
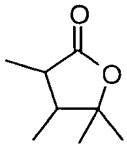
[0324]

Examples 15-1 to 15-8

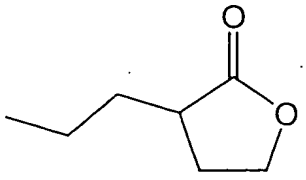
To an ethyl ether solution (7 ml) containing any of 8 kinds of olefin alcohol ester 15A (1.0 mmol) shown in Table 22 and tetraisopropoxytitanium (1.3 mmol) was added at -50° C an ethyl ether solution containing isopropylmagnesium chloride (2.6 mmol). The reaction liquid was stirred at -50 to -40° C for 1 hour. With 5 ml of 3N hydrochloric acid added, the reaction liquid was separated into layers. The organic layer was dried with anhydrous magnesium sulfate and freed of solvent by vacuum distillation. The residues were purified by silica gel chromatography. Thus there were obtained samples of 15B in lactone form or ring-opened form in respective yields as shown in Table 22.

[0325]

Table 22

Example	15A	15B	Yields (%)
15-1			92
15-2			92
15-3			89
15-4			86
15-5			79
15-6			30
15-7			89
15-8			46

[0326]

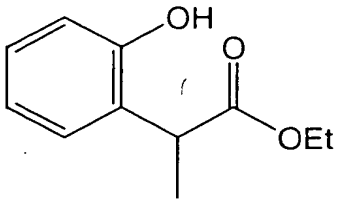


5

[0327]

^{1}H-NMR, δ: 0.98 (t, J=7.3 Hz, 3H)
0.35 (q, J=7.3 Hz, 2H)
1.80-1.90 (m, 2H)
2.30 (m, 1H)
2.45 (dt, J=1.1, 4.7 Hz, 1H)
4.13 (dt, J=9.2, 6.6 Hz, 1H)
4.28 (dt, J=9.1, 2.9 Hz, 1H)

[0328]



[0329]

^{1}H-NMR, δ: 1.24 (t, J=7.4 Hz, 3H)
1.53 (d, J=7.0 Hz, 3H)
3.90 (q, J=7.0 Hz, 1H)
4.28 (q, J=7.5 Hz, 2H)
6.80-7.20 (m, 4H)
7.70 (s, 1H)

[ABSTRACT]

[Constitution]

A titanium catalyst for reaction between a carbon-carbon unsaturated bond and a compound having an electrophilic functional group or an electrophilic reagent, said titanium catalyst being composed of a titanium compound represented by the formula (1) below

$$TiX^1X^2X^3X^4 \qquad (1)$$

(where X^1, X^2, X^3, and X^4 denote independently a halogen atom, C1-20 alkoxyl group, aralkyloxy group, aryloxy group, or -NRxRy group (where Rx and Ry denote independently a C1-20 alkyl group or aralkyl group), and any two of X^1, X^2, X^3, and X^4 may form a ring.) and a Grignard reagent represented by the formula (2) below in a molar amount 1-10 times as much as the titanium compound.

$$R^1MgX^5 \qquad (2)$$

(where R^1 denotes a C2-10 alkyl group having a hydrogen atom at the β position and X^5 denotes a halogen atom.).

[Effect]

According to the present invention, the titanium catalyst activate the carbon-carbon unsaturated bond whose activity is comparatively low, thereby catalyzing the reaction with the electrophilic functional group. They are inexpensive and industrially advantageous. The titanium catalyst and the organotitanium reacting reagent bring about the reaction between the carbon-carbon unsaturated bond and the electrophilic functional group, so that they give rise to a variety of addition reaction products from a compound having a carbon-carbon unsaturated bond and a compound having an electrophilic functional group in an industrially advantageous manner or they give rise to a variety of intramolecular addition reaction products of compounds having a carbon-carbon unsaturated bond and an electrophilic functional group in the same molecule.

[Selected Drawing] None